Free! 89 Calendar of Galactic Events ■ Discovery's Liftoff: An Insider's Story ■ Le Shuttle Français ■ Dan Rather on NASA's Comeback ■ Confessions of a Soviet Cosmonaut ■ Firefighting From Space

FINAL FRONTIER

The Magazine of Space Exploration

February 1989

Special Report!

SPACE: THE NEXT TEN YEARS

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America needs the Space Station.

The Space Station is our first step to the stars. And it's time to begin.

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now in space research to speed our rate of invention and create new jobs based on advanced technology.

In addition to the immediate benefits of this great challenge — new technology and new jobs — the Space Station is a stepping stone toward Mars.

We should build it. Now.

BOEING

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January/February 1989
Volume 2, Number 1

There's going to be a lot happening out there in the next decade. For a preview, see the special report beginning on page 23.

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MCDONNELL DOUGLAS

FROM THE PUBLISHER

I'd almost forgotten what got me into this business in the first place.

Being a publisher, it's easy to get lost in the numbers. You spend a lot of time counting beans, and sometimes The Universe shrinks down to the size of a spreadsheet. So it was nice to find myself looking up again.

September 29, 1988 was a day of renewal for a lot of us. It had seemed so long since we last watched that bright fire climbing into the sky. And now there it was, the pure essence of this magazine's mission, rising from a Florida launch pad toward the future.

I'd be lying if I told you we have no regard for the bottom line around here. But that's not what fuels the fire. Watching Discovery go, I couldn't help but think that somehow, in some small way, FINAL FRONTIER—the staff, the readers and our collective spirit of adventure—had contributed to its motion. What keeps me going is the belief that we help out by inspiring both the space "establishment" and the new wildcatters to aim higher.

The U.S. space program has suffered its own version of the shrinking Universe in the past three years. Instead of spacewalks and planetary fly-bys, it's been O-rings and safety regulations. All necessary work, but hardly the stuff of dreams. And nowhere near as exciting as the plans you'll find outlined in this issue.

That's why, when we started tallying up all the projects on deck for the next ten years in space, it got our pulses going a little quicker. We'd heard that the U.S. space program was comatose, with no plans and no ideas. But there's enough excitement here for *two* decades. There's the Hubble Space Telescope, maybe the most revolutionary scientific instrument of its time. Then there's space station Freedom, our first real outpost on the new frontier. And some of the advanced vehicles on the drawing boards hold the promise that more of us may be going up there soon, to look around for ourselves.

True, a lot of these projects were set in motion years ago, in the halls of Congress and in space centers around the country. The Challenger accident caused a traffic jam, and now the traffic's moving again.

And our job is to make sure it keeps moving.

What's planned for the 1990s is only a start. If we want to head out for the Moon, Mars and points beyond, we need to get cracking today, right now. That means all of us—the leaders, the public that has to keep demanding vision from those leaders, and this magazine, whose role is to keep looking *up*.

If we all do our jobs, the *next* Next Ten Years in Space will be even more spectacular.

Ever upward,

William Rooney

William Rooney
Publisher

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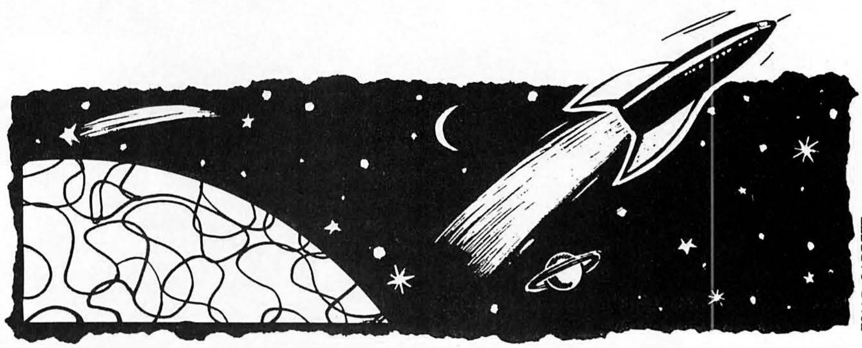

TOM R. GARRETT

Beating the Iron Triangle

I read Walter A. McDougall's essay "Space, Politics, and the Next President" (October 1988) with interest, particularly as I am the co-author (with Phillip K. Salin) of the Reason Foundation study mentioned several times in the article. I am in agreement with much of what he said, and I appreciate his judgment that we made a strong case for privatization. However, I would disagree with his subsequent comment that we ignored "the structural interest groups and entry costs that would make sweeping privatization politically and financially painful." Our discussion of the "Iron Triangle" effect, which he referred to several times, contains a fairly lengthy treatment of precisely those structural groups, and the chances of overcoming the negative effects of their influence. Perhaps he means to say that we did not convince him that those interests could be overcome.

As to the question of entry costs, his essay displays a tendency (which appears elsewhere in his work) to accept the entry costs which have prevailed to date in space transportation as inherent to the industry. This assumption leads to the conclusion that space transportation has been dominated by the "military-industrial complex" because it is expensive, whereas we argue that space transportation is expensive because it has been carried out until now exclusively by those interests. My own work at the American Rocket Company has reinforced my belief that the entry costs for space transportation are not inherently huge.

The heart of our argument is that a change in incentive structures is the only effective remedy for the problems which continue to plague American efforts in space. A growing influx of genuinely private operators, allied with those interests in the government which are strongly results-driven, such as parts of the defense community, is the trend most likely to drive these incentive structure changes. (This is also the most likely way to harness the "young, bright talent" which McDougall refers to.)

As to the chances of overcoming the entrenched interests and implementing privatization, I feel that there are good reasons to expect it to succeed. I suggest that readers interested in the question acquire our study and decide for themselves. The study, entitled *Privatizing Space Transportation,* can be obtained by sending $5.00 to the Reason Foundation, 2716 Ocean Park Blvd., Suite 1062, Santa Monica, California 90405.

James C. Bennett
Vice President, External Affairs
American Rocket Company

At the Forefront

Add my relief and thanks for an ultra-modern, up-to-the-minute and beautiful ultra-space magazine. I am 68, and expect to subscribe to FINAL FRONTIER for at least the next 40 years. My thanks also to our American space scientists, engineers and many related workers who have taken us this far, and will take us into the future.

I am firmly and irrevocably convinced that in the limitless vigintillions of centuries ahead, America will still be in the forefront of space exploration and exploitation.

Kenneth Yale Whipple
Goodrich, Michigan

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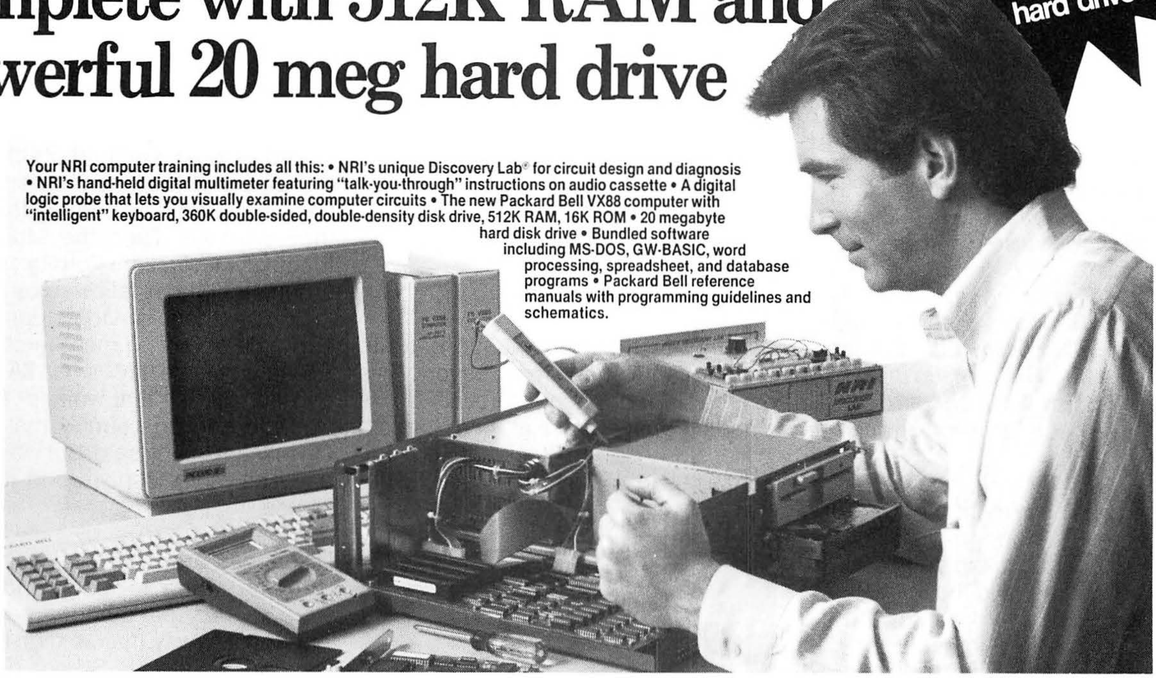

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THE OBSERVATORY

Confidence Regained

An anchorman's thoughts on our return to space.

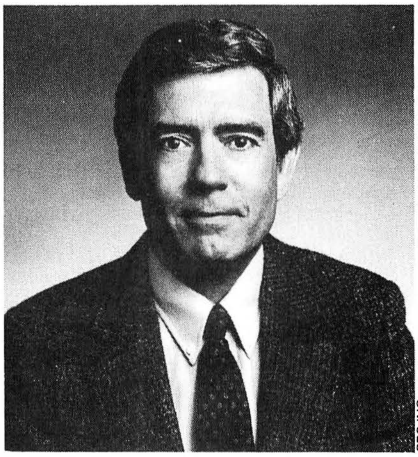
▼ ▼ ▼

By Dan Rather

Dan Rather has a reputation as a tough but fair-minded newsman, the kind who gives NASA its lumps when they are deserved, and praise when the space agency earns it. His radio program, "Dan Rather Reporting" airs daily on the CBS Radio Network. Last September 29—the day Discovery put Americans back into orbit—Rather used the broadcast to reflect on his years of reporting America's space triumphs...and its tragedies.

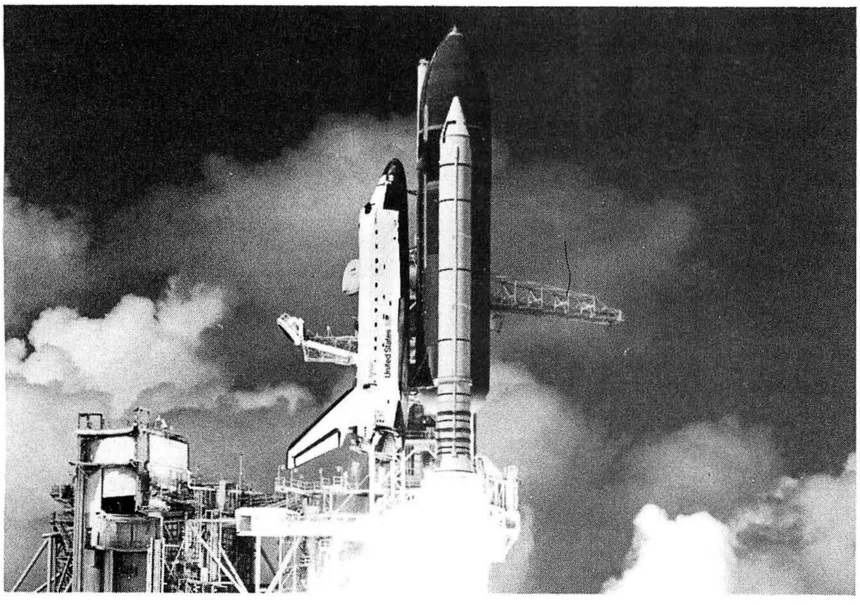
It was early in the Florida morning, before daybreak. We were helicoptering in the dark, over the Intercoastal Canal and the marshlands below, toward the future—toward the Space Center. Suddenly there it was, bathed in white light, condensation rising like smoke from its base. Mystical, magical launch pad 39B, where the spaceship Discovery was stacked and waiting. Rushing through a reporter's mind, a blur of thoughts and images, memories and anticipation.

I remember the first time I saw the Cape. That's what we called it then, "the Cape." Cape Canaveral. We drove in then, through mist and low ground fog. And that first sight of launch pads to space—and the great beyond—is etched in one mind forever. So is standing on the grass at Rice Stadium in Houston, hearing President Kennedy commit us to going to the Moon. To the *Moon.*



CBS INC.

Discovery clears the pad.



And all those Apollo shots, the fire on the pad and the haunting specter of trapped astronauts burning to death in their capsule. Then the Moon shots themselves, first the orbital missions around the Moon, followed by the landing on it—those first footsteps, and our euphoria at having met the challenge. These were the 1960s. NASA was the can-do agency that worked, and ours was the can-do country that worked. On to Mars, many said. But many *didn't,* and some of those were in the White House.

It was the 1970's by now. Richard Nixon was president. He wasn't interested in going to Mars, and neither were a lot of other Americans—enough, anyway, that we didn't commit, we didn't go after it. Slower, go *slower.* Spend less and try less, we were told. And Mars, forget it. Maybe some day, but not now.

The consolation prize was building the space shuttle. It was the very least of the major options, the least of the big goals. Not very imaginative, not even very big, just a kind of little something to keep the space agency going. So we forgot about Mars and settled on the shuttle, a kind of space truck for hauling people and gear into space. Develop the shuttle we did, the best we could, and that was good—very good.

The space shuttle is the most complex flying machine ever built. It probably will remain so through the end of this century. It takes off like a rocket, maneuvers in orbit like a spacecraft, and lands like an airplane. The shuttle is humankind's first, and to this day, only, true spaceship. More than two dozen times we put it up and got it down. And then, disaster. Shuttle Challenger—the beautiful, beautiful Challenger—exploded in mid-air, and with its crew, was gone forever.

With Challenger went some—no, went a *lot*—of our confidence. Today our confidence is back—up there, out there.

Its name—Discovery....

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NOTES FROM EARTH

YANKS BEAT REDS, 14-10

NASA's Wallops Flight Facility in Virginia is no stranger to the roar of rocket engines, but it was more a *woooosh!* than a rumble that sounded across the Delmarva peninsula early in October. For the first time ever, American model rocketeers squared off in head-to-head competition against a squad of modelers from the Soviet Union.

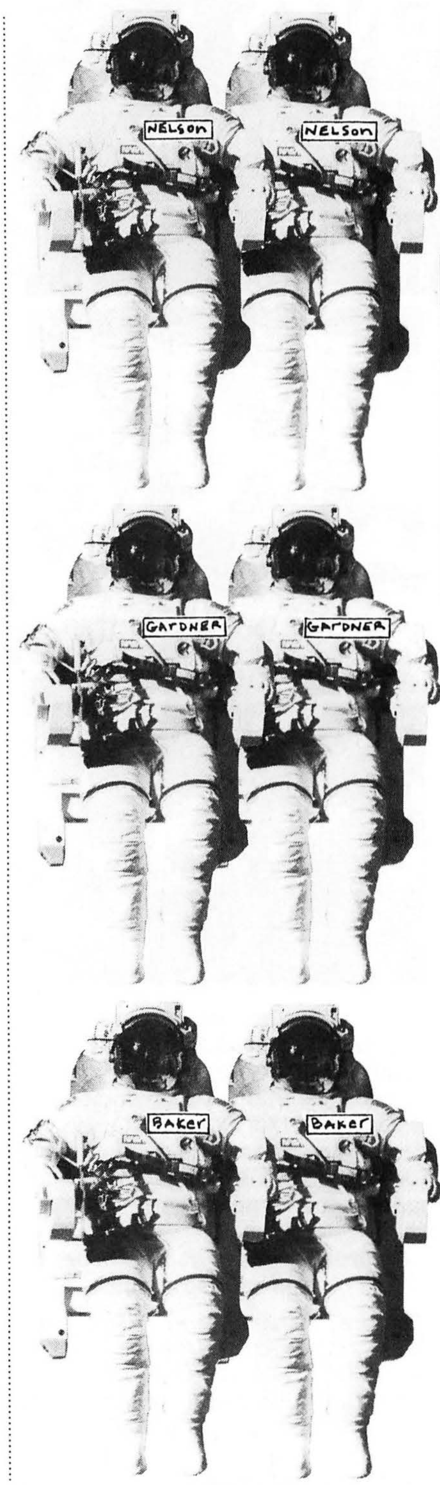
According to contest director Ed Pearson, the idea for this meeting of two very different worlds of model rocketry began three years ago, when U.S. and Soviet space-modeling representatives to the *Federation Aeronautique Internationale* (the same group that certifies record flights of real planes and spacecraft) began informal discussions. After a series of what Pearson calls "bureaucratic clearances" and fund raising efforts, an October 1988 target date was set for the Wallops competition, with a future encounter to take place in Moscow.

IAN DOWSETT

The American team won the meet, "placing" fourteen times to the Soviets' ten, but the spirit of competition took a back seat to the camaraderie of people with the same longstanding interest. Model rocketry—at least at this level—isn't a sport for kids; the participants ranged in age from late twenties to mid-fifties. Some had been flying model rockets since the dawn of the Space Age thirty years ago.

"They're just regular guys," said Phil Barnes of Maryland, one of the American rocketeers. "The Soviet team was really more interested in seeing the United States than in winning the competition." Ed Pearson echoed that sentiment: "It was a milestone event in this modeling arena, [but also] a chance for international cooperation and relations, cultural exchange and understanding."

If only we could keep all our worldly competitions this civil.... —*R. J. Karr*



DOUBLE DUTY

It was bound to happen sooner or later. Less than six months after Alexander P. Alexandrov returned to Earth at the end of 1987, Alexander P. Alexandrov was in space visiting the Soviet Union's Mir space station.

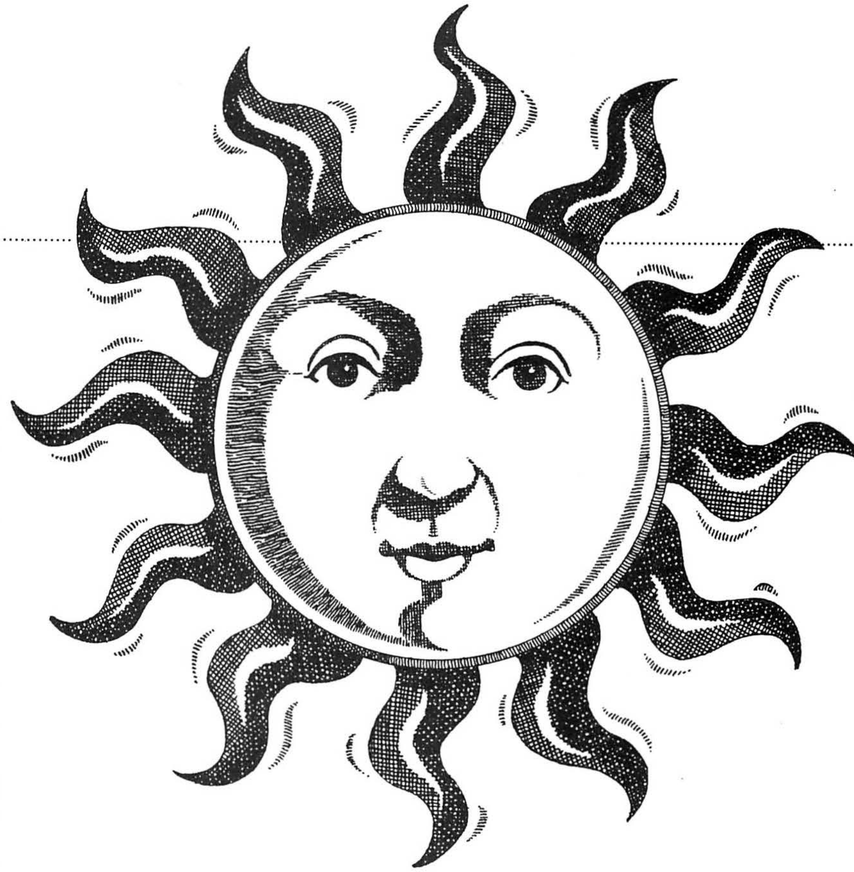
Same name, different guy.

By the middle of 1988, more than 200 humans had been in orbit. First names repeated after only a few years: the second "John" (Young) flew in 1965, "Vladimir" #2 (Shatalov) not long afterward. In the early 1980s, last names began to duplicate, some even doubling up on the same mission.

The crew patch for the last successful shuttle flight before the Challenger accident looked like the linotype stuttered— "Nelson" appeared twice. George "Pinky" Nelson was a veteran shuttle astronaut; Bill Nelson (*sans* diminutive nickname) was the congressman from Florida. And had the accident not intervened, the "double namer" effect would have occurred again a few months later. The first flight scheduled to depart the Vandenberg shuttle launch site in California listed *Guy* Gardner as pilot, two-time veteran *Dale* Gardner as a flight engineer.

Since spaceflight history was at stake, of course the Russians had to do things even better. In 1987 they selected a Bulgarian guest cosmonaut with the same last *and* first names (not to mention middle initial) as an experienced Soviet spacefarer. The Bulgarian "Alexander P. Alexandrov" was on the second team for the failed Soyuz 33 flight in 1979, then was chosen for a June 1988 re-flight along with a backup pilot named Stoyanov (whose brother—another Stoyanov—*also* was a candidate for the mission!).

What's to come? NASA could fly the two married shuttle veterans, Bill and



BILL REYNOLDS

Anna Fisher, together. Another female astronaut named Shulman now uses her new husband's last name of Baker, while an unrelated "Baker" was selected for the 1984 astronaut class.

Meanwhile, double-name aficionados will have to make Columbia's copilot for the shuttle's STS-28 mission next July their hero. His name? Richard Richards. *–James E. Oberg*

DIAL-A-TARGET

Around and around the space shuttle goes. And where it stops in the direst of emergencies, hardly anybody knows...including those who own some of the 30 or so contingency landing sites that dot the globe.

Don't confuse these runways with the ones where orbiters are *supposed* to land after a mission. Or with those sites where an orbiter *could* land after a bad launch–like the four designated abort sites in Europe and Africa, which NASA says are for a "true emergency."

The space agency has equipped these transatlantic (or "TAL") abort sites in Spain, Morocco and Gambia with everything a shuttle needs to touch down safely: navigation and landing aids, weather radar, firefighters and paramedics, runway lights, even arresting nets near the end of the pavement to catch the vehicle should it overshoot its landing.

But NASA will say only that the *backup* emergency runways meet "the criteria" for unplanned landings. They include "U.S. sites, Department of Defense bases around the world and non-U.S. sites."

Apparently, those non-U.S. sites are the reason the list isn't public. "There may be countries that prefer we don't give out their names," says Debbie Rahn, a NASA international affairs spokesperson. "Besides," Rahn adds, "we're not prepared to give out a list of those potential emergency landing sites when the governments–some of them–are not even aware they're *on* the list at this point."

For each mission, emergency landing coordinates are programmed into an orbiter computer that space agency insiders nicknamed "Dial-a-Target." Orbiting shuttle crews can punch up landing strips to match their trajectory. NASA won't say, but rumor has it that Orlando International Airport, a 45-minute buzz across the Bee Line Expressway from Kennedy Space Center, is one of the sites.

Even as Discovery returned the shuttle to flight in September, NASA still was checking with U.S. embassies near the foreign sites to make sure its list was viable. "Our intent is always to come home if we can," Rahn points out. But "when you have to come down, you have to come down." *–Beth Dickey*

AND WE'LL HAVE SUN, SUN, SUN

Ready for a cosmic show? The Sun is on its way to reaching the height of another sunspot cycle–and experts say that the peak of "Cycle 22" in 1990 may rival that of 1958, the strongest ever recorded.

Be ready for stunning auroral displays and an additional shot of ozone to the Earth's depleted ozone blanket, due to the action of solar radiation on oxygen in the atmosphere. Also be prepared for electrical blackouts and communication problems. But for NASA and other space agencies around the world, there is another

ERIC HANSON

NOTES FROM EARTH

NASA's fire-fighting ER-2 aircraft.

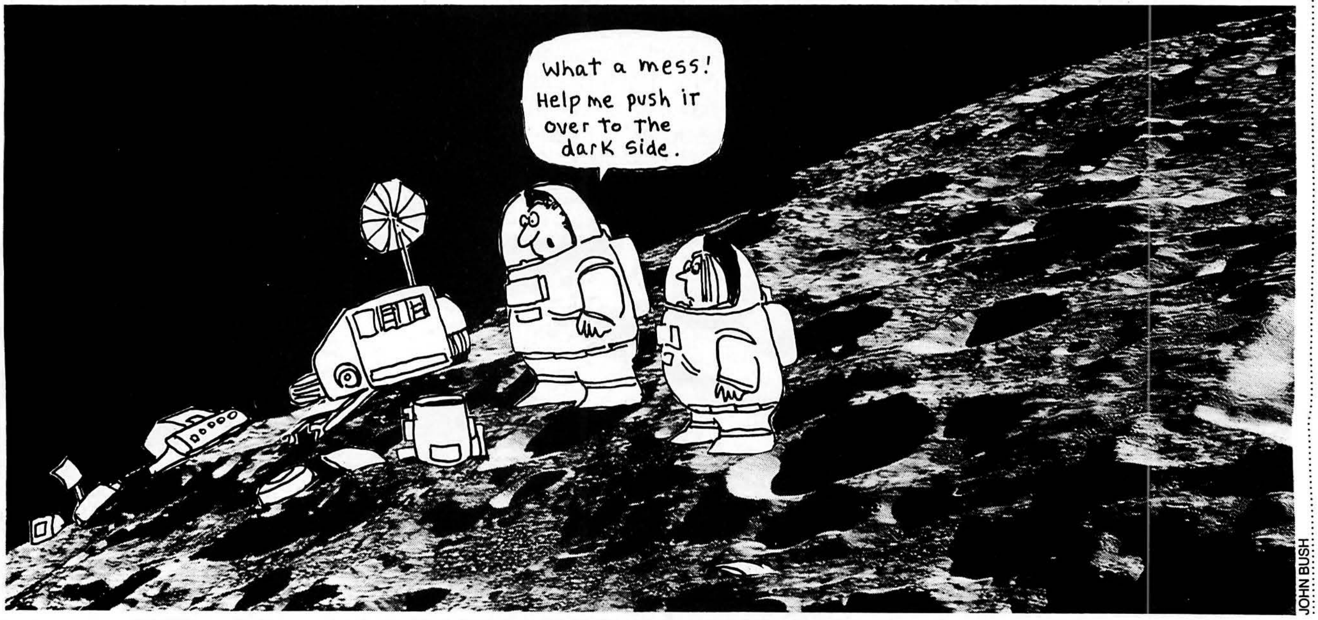
worry: radiation interference and atmospheric drag on orbiting spacecraft. "As the solar cycle reaches its peak, emissions from the Sun increase," says Joe Hirman, forecast operations manager at the Space Environmental Services Center run by the National Oceanic and Atmospheric Administration and the Air Force. "The emissions from the larger solar flares release the energy equivalent to what Man has used since he has been on Earth." Such great bursts of radiation during the peak of the cycle have the potential to do radical damage to satellite components. And the human "components" of an orbiting shuttle won't be immune; spacewalking astronauts may have to hustle inside as their vehicle quickly drops to a lower, more protected orbit. The geomagnetic storms that create striking auroral displays will also heat and expand the thin air of the upper atmosphere, resulting in increased drag on spacecraft in low orbits. That particular consequence offers one advantage: it will clear out at least some of the clutter of unused or discarded satellites. But atmospheric friction doesn't discriminate between space junk and functioning hardware. "NASA is concerned about several working spacecraft," says Hirman. "They're afraid the craft will re-enter the atmosphere before the shuttle can retrieve them." That fear isn't unfounded. On July 12, 1979, during the last sunspot cycle peak, the derelict Skylab space station fell back to Earth—the victim of a decaying orbit helped along by the increase in solar activity.

—Patricia Barnes-Svarney

WELCOME TO THE SPACE AGE, SMOKEY

NASA teamed up with Smokey the Bear late last summer when a voracious cluster of wildfires raged through Yellowstone National Park, devouring nearly half its 2.2 million acres. To make the best possible use of their 8,000 to 10,000 firefighters, forest service strategists needed the most recent and accurate information they could get.

Enter Vince Ambrosia and Jim Brass from NASA's Ames Research Center in California. As part of the space agency's "Mission to Planet Earth" research, these environmental experts constantly watch data from Earth-viewing satellites operated by the National



Oceanic and Atmospheric Administration, checking the contribution of fires to atmospheric pollution on a global scale. When the Yellowstone blaze raged for an agonizing three months, they gathered up a NASA team and headed for Wyoming.

In September, NASA's ER-2 aircraft (a modified version of the U-2 spy plane) flew in from the coast to scan the Yellowstone area. At 65,000 feet, the ER-2 soared high above the smoke plumes, its instruments penetrating their thick layers to make an infrared map of 80% of the park in a single two-hour flyover.

Meanwhile, the NASA team rigged a special communications setup from the aircraft to Yellowstone so that forest rangers could have instant access to their remote sensing data and analysis. Says park spokesperson Joan Anzelmo, "When you're fighting fires in the wilderness, you can't tell where the hot spots are. NASA's service was invaluable to us."

Ambrosia notes that such a fire is "ecologically part of the natural system." Still, he adds, a unique set of circumstances–destruction of timber by a severe beetle infestation, a three-year drought, unseasonably high winds and dry lightning strikes–combined this summer to make Yellowstone "a time bomb waiting to go off."

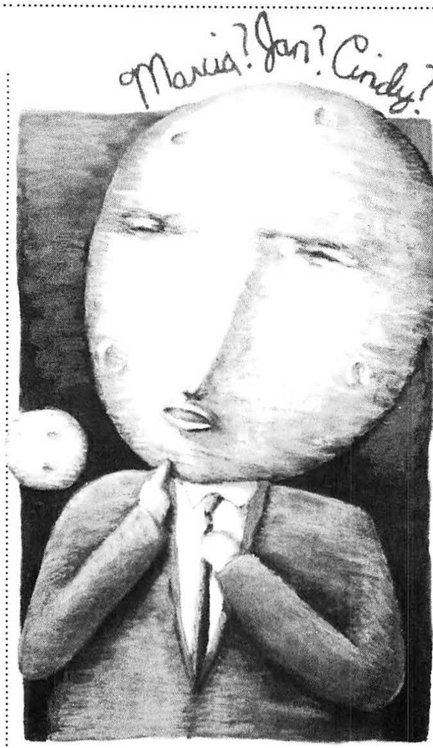
–Ray Spangenburg and Diane Moser

LUNAR ECOLOGY

While most long-term space planners are working on the problem of how we'll protect the first Moon settlers from the harsh lunar environment, chemical engineer Randy Briggs wants to turn the question around: How will we protect the Moon from Man?

Briggs, a doctoral student at Worcester Polytechnic Institute in Massachusetts, has forecast the possible environmental effects of generating power, mining and transporting people to the Moon, not to mention all the daily functions of living, breathing human beings on the surface. His objective, he says, was to promote the idea that once certain planning decisions are made, "there's no turning back."

It's the Moon's pristine state, of course, that prompts much of the desire to return. Geologists want to examine the lunar surface for clues



RICK PETERSON

about the state of the Solar System at a much earlier stage in its development, and astronomers hope one day to erect a large telescope on the Moon's far side. Alteration of the surface, or the creation of an obscuring atmosphere from manmade chemicals, would defeat some of the very reasons for going back.

In two areas, Briggs found little cause for worry. There's little or no danger that emissions from transport spacecraft will create an artificial atmosphere, although peak flight rates could affect lunar astronomy. Likewise, the byproducts of human chemistry pose few problems, since NASA planners assume that carbon dioxide and waste water should be recycled.

On the other hand, Briggs says, the mining of lunar soil to support operations on the Moon could leave lasting damage. By his calculations, miners would have to dig a two meter-thick plot the size of six football fields to harvest 1,000 metric tons of oxygen, which would be used for rocket propellant and other purposes. If the unused soil isn't "backfilled" after processing, huge strip mine scars would be left behind, which could possibly be visible from Earth.

Briggs says it's critical that ecology become a basic element of lunar planning–now. "We've got to change our traditional ways," he says, "and learn from the mistakes we've made on Earth."

–Henry Fuhrmann

NAME THAT MOON

Half of them you can't pronounce. The other half sound like a role call for a Shakespearean festival. But to a subcommittee of the International Astronomical Union, names like Belinda, Rosalind and Desdemona are part of their job– christening the many newfound members of the Solar System community. "If we don't officially give names, names spring up informally," said astronomer Tobias Owen, who chairs the IAU subcommittee that determines planetary and satellite nomenclature. "And that gets confusing."

Owen and ten other scientists, including representatives from the Soviet Union, France, Norway and Italy, have been busy in recent years–especially with the visits by Voyagers 1 and 2 to the outer Solar System. When naming newly discovered satellites, the group tries to adhere to traditions set up by earlier discoverers.

That's why, when Voyager found ten "new" moons orbiting Uranus in 1986, the IAU subcommittee rejected suggestions that some of them should honor the Challenger astronauts who had died even while Voyager 2 was rounding the planet. "The names chosen were from Shakespeare's plays and Alexander Pope's poem *The Rape of the Lock*," says Owen. For example, one 170-kilometer- wide chunk of rock orbiting Uranus now bears the unlikely name "Puck"–the elf-like character from *A Midsummer Night's Dream.*

Next August Voyager 2 will fly past Neptune, where it will no doubt find more satellites in need of names. The "theme" is already determined: the IAU will follow the long-standing custom of naming Neptune's closest neighbors for spirits, beings, goddesses or gods associated with the Roman god of the sea, also known (to the Greeks) as Poseidon. The names "Triton" and "Nereid" are already taken, but among those in Neptune's crowd who *haven't* yet been honored with their own satellites are his son Proteus and Leucothea, the patron goddess of sailors lost in a shipwreck.

–Patricia Barnes-Svarney

BOUNDARIES

Lunar Excavations

Booming business on the Moon

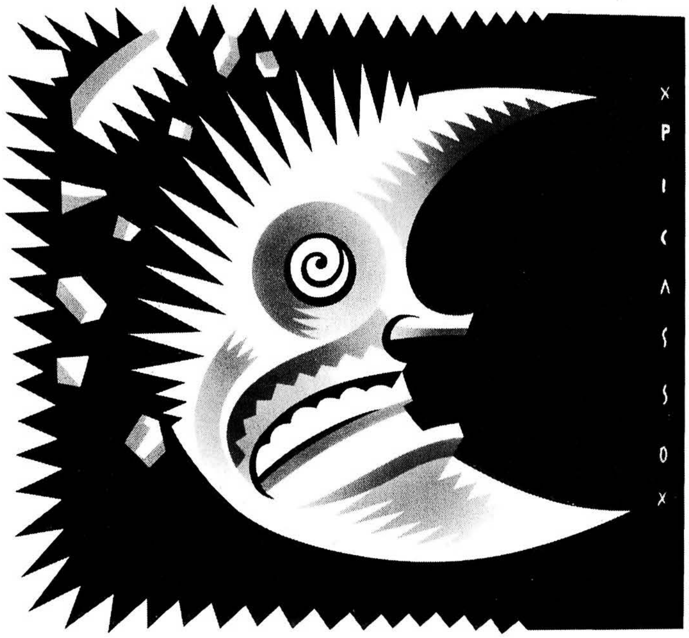
▼ ▼ ▼

By Patricia Barnes-Svarney

Caught between a rock and a hard place? On Earth, the solution often calls for a stick of dynamite, a hard hat and a long fuse. But on the Moon, breaking ground for new construction projects is going to be a lot more complicated.

To use explosives or not to use explosives–that's the difficult question facing long-term lunar planners. The main reason for looking into the use of explosives on the Moon stems from NASA's recent interest in establishing a permanent lunar base–a scientific outpost that may also be a steppingstone to a Mars colony.

"If you look at the post-Apollo exploration era, the plans were to send up space station modules to the Moon and bury them in the lunar soil for protection," explains Wendell Mendell, chief scientist for lunar-based studies at the Johnson Space Center in Houston. "But if you are going to have a permanent facility, that sort of design is not good for a productive work environment or place for people to live. There must be some kind of construction technique developed."



DAN PICASSO

But consider the problems of transporting enough lunar bulldozers to excavate the land and make room for the Moon base's labs, observatories and spaceports. Launching all that equipment directly from Earth requires at least 22 times as much energy as lifting a similar amount from the Moon. The sheer weight of the task is a major factor favoring the use of explosives.

When it comes to blowing up things, the Moon is literally a new world. The wide range in lunar temperatures–from +240 degrees to −280 degrees Fahrenheit, may affect the properties of whatever explosives are used. Eons of bombardment by meteorites has left the Moon's surface strewn with rubble; the unconsolidated rock might be unstable during an explosion, raising the potential for a dangerous landslide. Probably the most vexing problem is the Moon's low gravity, one-sixth that of Earth. Given enough energy, particles from an explosion might be blasted into lunar orbit.

Right now, the reluctance to consider using explosives in space has to do with thirty years of experience. "There seems to be an engineering culture gap," Mendell says. "NASA is full of rocket scientists who believe that explosives are something you keep in a rocket or stay away from if at all possible.

Once we get people who are experienced in construction involved in thinking about these things, we will have new ideas– and one may be the use of explosives on the Moon in a controlled way."

Paul Weiblen, director of the Space Science Center at the University of Minnesota, agrees. "Those technologies [for handling lunar explosives] are not on hand, but they could be developed–they would always have to be weighed against the alternatives."

Researchers are working hard to find those alternatives. One proposed device–a plasma torch–would be similar to the acetylene torches used in Earthly rock quarries. Using solar radiation for an electricity source, modified plasma torches might be able to chip the surface of lunar rocks, and eventually help to cut out blocks of bedrock.

Microwaves also may provide another nonexplosive choice. If a tight microwave beam is properly tuned on a rock, the minerals within the rock would expand from the heat–much like an ordinary microwave oven. Each type of mineral within the rock expands at a different rate, thus crumbling the rock and making it easier to dig out. And there is so little water on the moon that the microwaves can deeply penetrate the moon's surface.

Even if other high-tech excavation methods are adopted, explosives shouldn't be ruled out. For example, they may one day be used as an emergency safety feature on the Moon. "If astronauts are out during a large solar flare event," suggests Weiblen, "they would have to quickly shield themselves from the intense radiation. Perhaps an explosive charge could be used to form a cavity in which to hide."

But for many space engineers, there will always be a negative gutreaction to the idea of using explosives on the moon. It seems dangerous, and it is. "But if you saw what people were doing with the controlled use of explosives," says Mendell, those same engineers might gain enough confidence to "satisfy all the issues." □

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GLOBAL CURRENTS

Japan's "Town of the Stars"

In Usuda, the future is now.

▼ ▼ ▼

By Jack D. Kirwan

The little town of Usuda (population 16,300) lies in Nagano Prefecture, in the heartland of Japan. What sets it apart from dozens of other prosperous, hardworking Japanese *machi* is that Usuda calls itself the "Town of the Stars" and seriously aspires to be one of Japan's major space centers.

Slowly but surely, Japan is becoming a major power in space. Unlike the Soviets, who rely for the most part on tried and true technology, or the Americans, with their hurry-up-then-do-nothing-for-years mindset, the Japanese are following a rational, long-range plan for moving into space. In August 1986, they launched a booster called the H-1, capable of putting 1,200 pounds in orbit. In 1992, it will be succeeded by the H-2, which will have almost four times the H-1's lifting capacity. A laboratory module for NASA's space station Freedom and a Japanese mini-shuttle are also in the planning stages.

In some ways, Japanese culture seems suited to space travel. There's an emphasis on competence, good manners and politeness, all useful qualities for getting along together in cramped spaces. In some respects, it's an ideal model for life in an orbiting station or lunar base. And Japanese landscaping and architecture, with their feel for miniaturized beauty and elegance, seem custom-made for life in space.

The town of Usuda entered the space age in 1984 when Japan's Institute of Space and Astronautical Science built a huge deep space tracking antenna on a hill outside its limits. Since Usuda is an inland town, it's unlikely ever to be a major launch site for rockets—although the current Japanese launch center, Tanegashima Island, south of Kyushu, is only used 90 days a year. (The locals claim that rockets scare the fish, and Japanese fisherman have a lot of political clout.)

Under the leadership of mayor Saichi Maruyama (a lively gentleman in his mid-seventies), Usuda opted for the next best thing: to make itself a space-theme-city. The town developed grand plans for a rocket-shaped observation tower, space park, museum of space science, planetarium, astronomical observation station and space convention center.

In November 1987, Usuda also established the "Federal State of the Galaxy," together with two cities and three towns that have similar institutes of space science. (*Federal State of the Galaxy* sounds more than a bit like science-fiction, but it's a fairly accurate translation of the more sober Japanese term.)

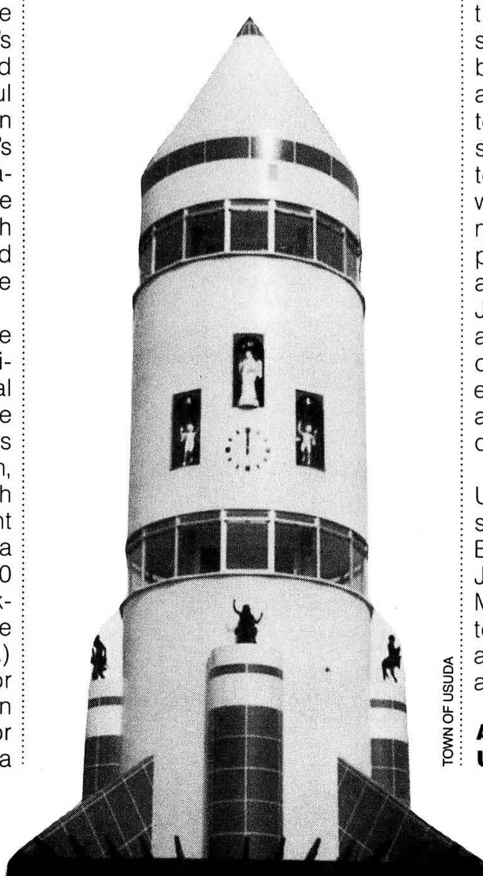
So far, only the rocket-observatory has been built. Like much of Japanese culture, it's a mix of science and mythology. At the top is a 360-degree observation area sectioned off into five "Republics," each named after a Japanese space science center such as Tanegashima. A town official says this is "to help the schoolchildren remember their country's space capitals."

Partway up the sides of the rocket are four small statues, each representing an astrological symbol. In local terms, this isn't so unusual: Japanese digital clocks, which can tell you whether your birthday decades from now will be on a Tuesday or a Wednesday, also have another button to tell you if it will be a "lucky" or "unlucky" day.

Inside the tower are a number of glass cases for exhibits. Right now, only a replica of the first Japanese satellite "Ohsumi," launched in 1970, is on display. A suggestion for the next exhibit is an international space station under construction, with a cutaway showing families "living, working and playing" in space.

There's also a curious Germanic touch. Four times a day, three doors in the side of the tower open up, and small, white angel-like figurines do brief mechanical dances to the accompaniment of chime music. The town officials believe this will be a showpiece for attracting Japanese tourists. Nagano Prefecture (the "state" where Usuda is located) is one of the most beautiful parts of Japan, with plenty of scenic mountains, skiing areas and hot springs. And like most of Japan, the past and the future in Usuda are as close as heads and tails on a coin. A bit down the road from the rocket tower, a thousand- year-old temple and stately three-story pagoda sit quietly in a pine forest.

In this age of megaprojects, tiny Usuda's plans to become a leading space center may seem like a dream. But Takashi Yamada, a manager for Japan's largest aerospace contractor, Mitsubishi Heavy Industries, makes a telling point. "The Japanese are good at going after dreams, once they look achievable." □



TOWN OF USUDA

A rocket-tower is only the beginning of Usuda's plans.

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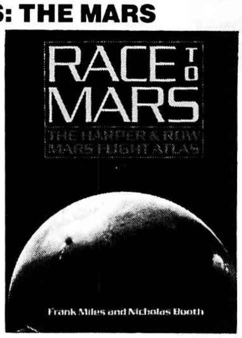

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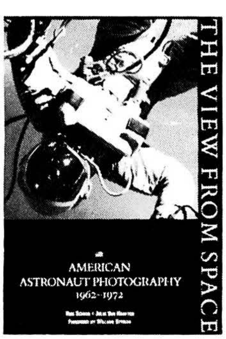

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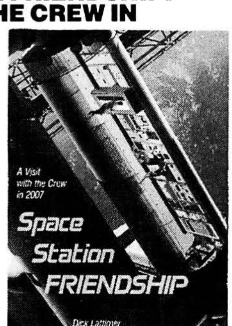

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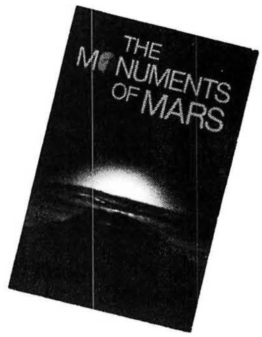

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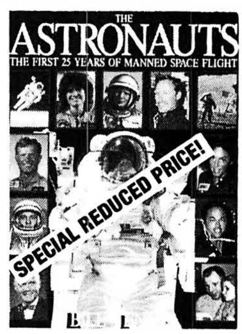

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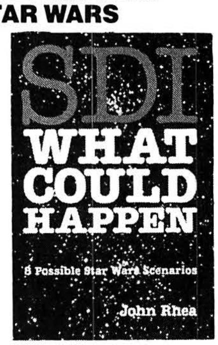

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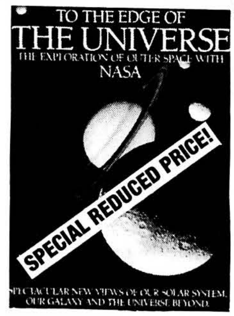

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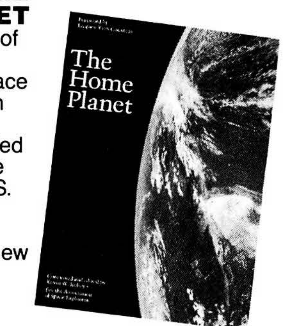

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EARTHLY PURSUITS

Keeping an Eye on National Treasures

A space-age camera checks America's personal papers

▼ ▼ ▼

By Robert Moulton

When the Galileo Jupiter mission and the Hubble Space Telescope begin sending back their pictures from space in the next few years, the results will flabbergast even the most sophisticated viewer of high-quality NASA photos. Everything will be done electronically, using the latest thing in astronomical sensors: charge-coupled devices, or CCDs. No film to recover, no processing to go wrong, no Voyager-type TV cameras.

That same CCD technology—which has been in development at NASA's Jet Propulsion laboratory for about ten years—is now being used in a camera at the National Archives and Records Administration in Washington, D.C. to monitor the health of our most prized national documents. The camera, mounted on a 6,000- lb. table of granite and steel, represents some of the most advanced image processing technology in use anywhere—even in space.

Charge-coupled devices are simply tiny pickups wired together in an array on a silicon chip. In the Charters Monitoring System, as the Archives apparatus is called, 1,024 of these sensors (or "photosites") make up an array that can see a 31 millimeter-long line of print on a document. Each photosite receives sensory data from a pinpoint along that line and gathers it, like water in a bucket. When the "sensor bucket" is full, the data are automatically dumped down the wire to a collection system. All the sensing and collection of data is done electronically; the camera has no film.

The data are then digitized and can be stored, transmitted or printed. By comparing the images that the camera has stored over time, the Archives preservationists can look for signs of deterioration in the documents.

"Obviously, we haven't seen any changes yet. It's too early," Archives preservation officer Alan Calmes said. Baseline photos of the Constitution were taken in September 1987, with follow-ups a year later. "We shouldn't see any changes in that short period of time, but with this camera and image processing system we will be able to see if any of our documents have stretched or faded, or if any ink has chipped off."

The camera will be used to monitor the "Charters of Freedom:" the Bill of Rights, the Constitution and the Declaration of Independence. It also will keep its electronic eye on other important national documents for which the Archives has responsibility. When documents go out on loan, they'll first be photographed; when they return, they will be examined by the camera again to see what changes, if any, have occurred.

The resolution and registration of the camera, which must be extremely precise, is controlled by a computer that checks for geometric distortions, focal position, uniformity of light source and system performance. A human controller executes commands from the operator console and sends data to the image processing computer and data log.

The Archives monitoring system is setting new standards of accuracy in the repetition and quality control of electronic images. Any apparent differences between one picture and the next are almost certain to be real, because the system precisely controls light levels, sensor temperature, camera focus and other variables.

The Jet Propulsion Laboratory, noted for its work with NASA's planetary probes, is the main contractor for the $3.3 million Charters Monitoring System. Calmes points out that the device took five years of design and development "even though we had used this image processing technology perhaps as early as the 1960s. This was an entirely new application of CCDs and digital image processing, and no one had ever built a camera like this."

The Archives is now seeking a qualified operator for the camera; until now, it's been Calmes' responsibility. "We'll be looking for a physicist or optical engineer trained in radiometry, optics or image processing," said the Archives preservationist. "The job will provide a unique advantage; it's all new, there's nothing like this anywhere, and it will provide really good opportunities for research and for the writing of professional papers."

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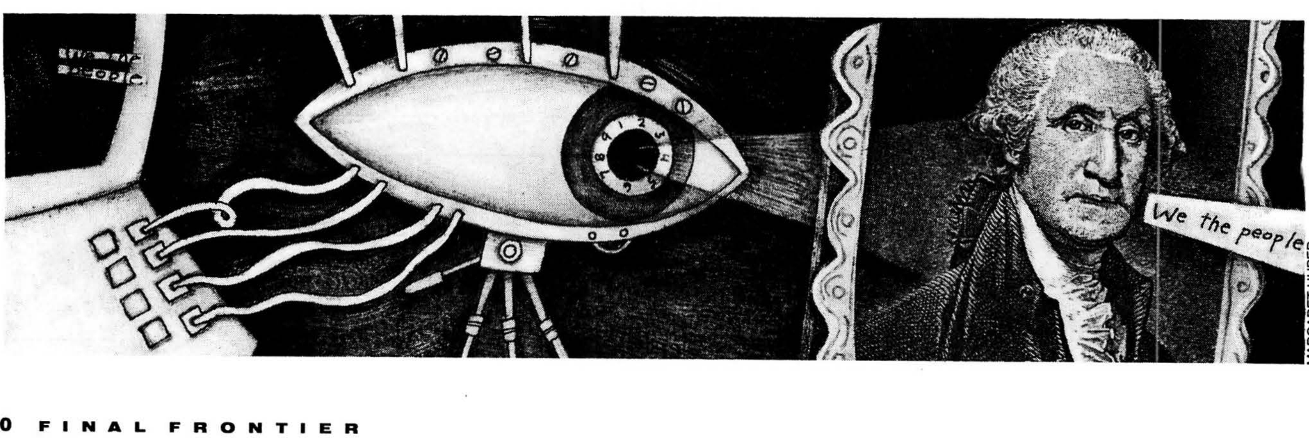

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SPECIAL REPORT

THE NEXT TEN YEARS IN SPACE

Predicting the future is a tough business. Hit the mark, and you're praised for your marvelous insight; fall flat, and people wonder how you could have missed the obvious.

Keeping in mind the perils of prophecy, FINAL FRONTIER asked a group of experts in space science, business and technology to give us a preview of what's planned—and what's possible—for the next decade. Some of the plans are speculative, others grounded in today's launch schedules and budget realities.

But if the forecasts are on target, the next ten years in space will be a rich period of exploitation as well as exploration, a time of evolutionary, and some revolutionary, steps.

We'll see our first close-ups of "new" planets (Neptune), moons (Phobos) and even an asteroid or two. The decade opens with the birth of one space shuttle program (the Soviet Union's) and the rebirth of another. In fact, Discovery's return to orbit will release a virtual flood of shuttle-borne projects, starting with the Magellan mission to Venus next April.

By decade's end, if the plans hold, we'll be test-flying a fleet of exciting new vehicles in orbit, from aerospace planes to heavy lift launchers. And, at long last, space will be *permanently* inhabited—by an international cast of characters from America, the Soviet Union, Europe and Japan.

And some people say there's nothing happening out there until the bus leaves for Mars....

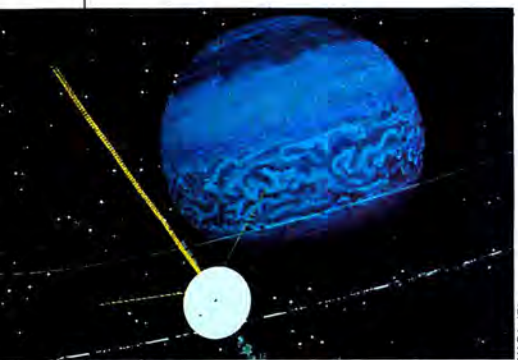
Before we roll the coming attractions, make sure you stash this issue of FINAL FRONTIER in a safe place. That way, ten years from now, you can write to tell us how we made out.

1989

Voyager Visits Neptune

Twelve years after it was launched from Earth, the greatest robot explorer our species has ever produced—the Voyager 2 spacecraft—will complete its "Grand Tour" of the outer Solar System with a swing-by of distant Neptune. When Voyager started its trek in 1977, only the most optimistic expected this magnificent creation to actually pull it off.

Voyager's encounter with Neptune on August 24-25 may be the most spectacular yet. Don't miss the show, because the planetary alignments and physics that made the Grand Tour possible this time won't allow another attempt until 2154.



NASA/JPL

August 24, 1989: Last stop on the "Grand Tour".

Expect Voyager's pictures of Neptune to resemble the views of Uranus sent back three years ago, which showed a smooth, fuzzy-looking aquamarine orb with hints of methane clouds circling high in its atmosphere. Instead of the continuous rings circling Jupiter, Saturn and Uranus, look for a baffling region of thin, spotty patches, or "arcs," of ring material, which planetary scientists hope Voyager will help to explain. Anticipate a magnetic field and a sizable magnetosphere.

The star of the show may well be enigmatic Triton—the largest of the two known Neptunian satellites, about the same size as our own Moon. Its surface may be sprinkled with shallow lakes of liquid nitrogen, perhaps surrounded by craters dusted with banks of water ice, methane frost and who knows what else. With a tenuous atmosphere, it joins Saturn's Titan as the odd couple among the moons of the Solar System. And it's the only major satellite orbiting in the *opposite* direction from its parent planet's rotation. No one is certain why, but Voyager 2 may provide clues.

Since this is Voyager's last planet, mission designers had the luxury of choosing the most exciting path through the Neptune system (in terms of scientific return) that mission safety, spacecraft performance and geometric constraints would allow. To no one's surprise, Triton was selected as a science focus equal to Neptune itself.

To pass closely by Triton (at a distance of only 25,000 miles), the spacecraft must be directed to pass ten times *closer* to Neptune. Inbound, it will zip just outside the postulated ring-arc region, aimed for a closest approach in the northern polar region just above the fringe of the atmosphere. There, it will be slam-dunked southward toward Triton by the strong Neptunian gravity field. It's a tricky maneuver, but doable.

All of this doesn't come easily. Allowing for sunlight levels at Neptune, which are 100 times dimmer than a moonlit night, forced several clever modifications to the spacecraft; in fact, it works better now than it did in 1977. Grueling last-minute updates to the onboard computer programs will be required to correct for uncertainties in navigation, as well as uncertainties about the physical constants of Neptune and Triton and Neptune's environmental hazards. An unprecedented array of Earthly antennas will be needed to capture the spacecraft's extremely faint radio signal, which will be traveling 2.8 billion miles from Neptune to Earth.

Successful completion of the Grand Tour in 1989 will mark the end of humanity's first wave of planetary reconnaissance. We'll have made all the stops in the Solar System, *sans* Pluto. Speeding past Neptune and Triton, Voyager 2 will continue to explore, joining its companions Voyager 1, Pioneer 10 and Pioneer 11 in a coordinated survey of the fringes of our Solar System—and perhaps the mysteries of interstellar space. —*Rex W. Ridenoure*

1989

The Hubble Space Telescope

On that day in December 1989 when NASA's Hubble Space Telescope is released into orbit from the cargo bay of the space shuttle, a new window on the universe will open.

Window on the Universe: Technicians prepare Hubble for launch.

Free of Earth's distorting atmosphere, this superb 94-inch reflector will offer unparalleled capabilities for studying the cosmos in visible and ultraviolet light.

Astronomers and astrophysicists have been waiting for years to crank up what will be, in effect, a time machine. The farther out we look, the further back we see, and the Space Telescope will allow us to see extremely distant objects that formed when the universe was very young. Astronomers will be searching for familiar objects—cosmic calibration markers—in distant clusters of galaxies, in their attempt to discover the true scale of the universe.

Hubble will help us to determine the rate at which the universe is expanding, and the rate at which this expansion has been slowing down over the eons. That information has profound cosmological consequences: we may learn whether the universe will expand forever, or if the expansion will stop, reverse, and come to a "Big Crunch" tens of billions of years hence.

The Space Telescope also offers the prospect of determining whether, as some astronomers suspect, there are massive black holes in the centers of some galaxies that power the enormous eruptions called quasars. We should be able to observe rapidly changing events in certain binary stars, where gas stripped from one star falls onto a neighbor with a powerful gravitational field, flashing brightly as it drops. Other investigators will search for the likely existence of a high-speed pulsar at the heart of Supernova 1987A—the throbbing remains of the most brilliant stellar explosion seen since Kepler's time.

The universe is full of gas—literally—and Hubble will scrutinize it more thoroughly than ever before possible. Its spectroscopes will investigate the chemical composition and physical state of gas between the stars,

and of the hot "coronas" around certain galaxies. By measuring the location and motion of stars with unparalleled accuracy, the Space Telescope may even establish the reality of planets around other stars. Closer to home, Hubble's sensitive cameras should give us our first decent look at Pluto and its mysterious moon Charon, and its view of the outer planets will be surpassed only by the close-up pictures taken by Voyager and Galileo.

The Hubble Space Telescope is the first of NASA's "Great Observatories," a suite of four long-lived orbiting instruments tuned to different parts of the electromagnetic spectrum, and designed to give scientists a more complete picture of the universe as a whole. One by one, the Gamma Ray Observatory, Advanced X-Ray Astrophysics Facility and Space Infrared Telescope Facility will join Hubble in orbit during the 1990s. But the Space Telescope won't be abandoned: space shuttle crews will revisit it periodically to replace worn parts and to install new instruments, including infrared sensors, that will upgrade the capabilities of this powerful orbiting observatory.

On the eve of the Hubble Space Telescope's launch, we aren't even sure what new questions its improved vision might raise. Future historians may one day look back on the 1990s as the decade that revolutionized our understanding of the universe. And Hubble will be remembered as the instrument that first cracked open the window.

—Stephen P. Maran

1992

Factories in Orbit

Five hundred years after Columbus discovered America, a new form of commercial trade will begin on a new frontier.

MARK DOWMAN/SPACE INDUSTRIES INC.

The Industrial Space Facility: Commercializing the last frontier.

Columbus wanted to find a shorter route to Asia to bring back precious cargo; the advent of the Industrial Space Facility (ISF), Spacehab and other privately funded commercial operations in orbit will signal the beginning of an era in which space-produced goods are sold on Earth.

The Industrial Space Facility proposed by the Houston-based Space Industries, Inc., will be a large metal cylinder about 14 feet in diameter and 30 feet long, which will provide enough pressurized volume, power and resources to support a variety of experiments or manufacturing operations in orbit.

Although it won't be permanently occupied like NASA's planned space station Freedom, the free-floating ISF will be visited routinely by the space shuttle to allow human "tending" of onboard experiments for up to several weeks at a time. Power will come from solar panels, and the experiments will be monitored and even controlled from the ground. The first ISF is designed to remain in orbit after launch from the shuttle in 1992, as a "mini-factory" supporting different experiments and operations over the course of its lifetime.

Washington-based Spacehab, Inc., has a different plan. The company wants to add extra room to the shuttle itself to accommodate many more experiments than can now be done in the orbiter's mid-deck area. The first version of the pressurized Spacehab module, scheduled for launch in 1991, will be bolted into the shuttle's cargo bay, but future models could be attached to the space station and left in orbit to provide extra laboratory space for commercial experiments.

A third concept is proposed by both the External Tanks Corporation (ETCO), and Global Outposts, Inc. to take advantage of the shuttle's huge external fuel tanks, which are now allowed to re-enter and burn up in the atmosphere after a launch. With a slight change to the shuttle's launch trajectory, the tanks could be lifted into orbit to be modified and used for a multitude of purposes, from gamma ray telescopes to waste storage facilities for the space station, to enormous orbiting garages.

The entrepreneurs behind these facilities, while varying in their approaches, share a common vision of conducting commercial activities in space. But can they ultimately rival the success of the early North American traders? Their products will need to

THE NEXT TEN YEARS IN SPACE

1989

Soviet Phobos 2 spacecraft reaches Mars orbit in late January, prepares for close encounter with moon Phobos

First commercial launches of Delta, Atlas and Titan rockets

Magellan probe launched from orbiting space shuttle toward Venus

Scheduled first test flight of American Rocket Corporation's privately developed Industrial Launch Vehicle

Voyager 2 encounters Neptune and its moon Triton

Galileo spacecraft begins trek to Jupiter after launch from space shuttle

Hubble Space Telescope launched into orbit to observe the Universe in visual and ultraviolet light

1990

ASTRO-1 shuttle mission spends nine days in orbit studying supernovas and other astrophysical phenomena

Gamma Ray Observatory becomes the second of NASA's "Great Observatories" in Earth orbit

Chinese Long March rocket launches Asiasat satellite into orbit for paying customer

Planned first orbital launch of Conestoga 2 booster, privately developed by Space Services, Inc.

Shuttle-borne Space Life Sciences Laboratory spends eight days in space studying effects of microgravity on humans and animals

European Ulysses probe launched from the space shuttle to study polar regions of the Sun

Magellan spacecraft arrives in Venus orbit to begin eight-month radar mapping mission

have high value and low mass, due to the extremely high cost of launching cargo into space.

Materials such as semiconductors or biomedical products fit the bill. For example, X-ray "pictures" of protein crystals can be analyzed by supercomputers to determine the three-dimensional structure of the protein. This crucial information allows scientists to understand better the way proteins are involved in chemical reactions in our bodies. In turn, pharmaceutical companies can use that knowledge to design better drugs. The protein crystals aren't the products per se—rather, it's the information *inside* them.

Crystals grow better in space, partly because the lack of gravity reduces the motions of the liquid in which they grow. Also, the crystal doesn't "sag" under its own weight as it gets larger. Some protein crystal experiments already are being conducted on the space shuttle. Future commercial activities are planned onboard the Soviet Mir space station until facilities like ISF, Spacehab and other orbiting factories become available.

Columbus' voyage was intended to visit the Far East, but the discovery of the New World eventually overshadowed the venture's original goals. So too will the development of commercial space facilities lead to much greater benefits for humankind than we can imagine now.

—Byron K. Lichtenberg

1994

Soviet Shuttle Begins Operations

The time is 1994. After years of delays and redesign efforts, the Soviet space shuttle conducts its first truly operational mission by exchanging a science module and several crewmembers on the aging Mir-1 space station. In spite of severe criticism from elements of the Soviet space science community, and despite budgetary restrictions imposed even before its first flight in 1988, the winged "VKK" ("vozdushno-kosmicheskoye korabl," or "aerospaceplane") finally begins to show its value.

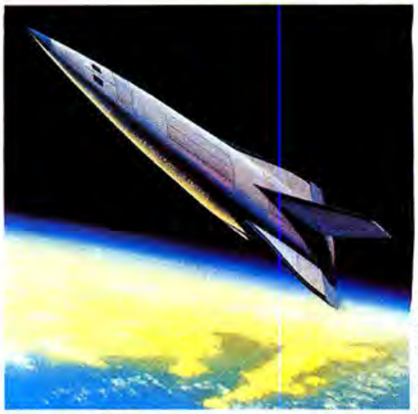
This is not the shuttle's first manned launch; test pilot cosmonauts rode it into orbit (with lift provided by the expendable Energiya booster) following the first fully automated flights in the late 1980s. Now the new, improved ten-man Sokol ("Falcon"), which replaces the prototype Buran ("Blizzard") and P'tichka ("Small Bird") vehicles, makes its flawless maiden orbital flight from the newly renamed "Korolev Cosmodrome" (formerly Baikonur). For the first time, it carries recoverable main engines that splash down in mid-Pacific an hour after launch.

Mission commander Leonid Popov, 48, leads his three crewmates and their six passengers on a complex series of orbital rendezvous maneuvers to reach the permanently occupied Mir complex, now in its eighth year of operation. Once docked to the station's front port, the cosmonauts use a "space crane" to remove one of Mir's four side-mounted research modules. After parking it out of the way, they extract a new module (loaded with a year's worth of life-support provisions) from the shuttle's cargo hold and link it to the empty port. The removed module, loaded with several tons of completed experiments, space-processed materials and crew equipment in need of diagnosis and repair, is then inserted into the empty space in the cargo bay and fastened securely.

While this is going on, three of the passengers change places with the long-term Mir crew that has just finished a 26-month orbital marathon. The other three shuttle passengers help out with the transfer. One, a doctor, performs the latest zero-G checkups on the old crew. Another, the USSR's (and the world's) first journalist in space, conducts interviews and takes photographs to document the occasion. The last passenger is chief Soviet space designer Konstantin Feoktistov, 68, making an on-site inspection of the results of his bureau's handiwork.

The prototype "Buran" vehicle awaits its first launch.

TASS/SOVFOTO



GENERAL DYNAMICS

The X-30: Making space flight routine

The two spacecraft are linked for less than 12 hours before the shuttle, which alone weighs as much as the six-module Mir, casts off. A few hours later it plunges back into the atmosphere for a fiery descent across the Middle East toward the miles-long runway in Soviet Central Asia, close to the launch point. The landing is entirely on autopilot, with the cosmonauts ready to take over or make adjustments only if needed.

Aboard Mir, the new crewmen inspect their attached Soyuz TM-28 capsule and prepare to receive a new supply ship of the Progress series. These spacecraft, launched on expendable rockets, have been in use since the 1970s and will continue supporting the Mir through the end of the century, even with the shuttle now operational.

Plans for using the Energiya heavy booster and the new shuttle fleet to launch and assemble the USSR's Mir-2 super-station are given a major impetus by this success (both NASA and the USSR are planning to assemble nearly identical stations in the second half of the decade). Domestic Soviet criticisms of the twenty-billion-dollar shuttle program finally grow muted as it becomes apparent that the money has already been spent, and that the vehicles could actually provide benefits to many different sectors of the ongoing Soviet space program.

To the relief of Western observers, none of the intended missions appears military in nature, which coordinates nicely with the American cessation of secret Pentagon shuttle missions. Once again, rivalry between the United States and the Soviet Union has spurred both nations on to activities in space that are far more ambitious than either would have attempted in the absence of foreign competition. Coordination and small-scale cooperation continue to grow, but the "Space Race" is once again in full swing.

—James E. Oberg

1994

The National Aerospace Plane

There has never been an airplane like this one. Long, slender and pointed, it is no larger than a medium-sized airliner, yet the tiny wings protruding from its fuselage will carry it to speeds 30 times faster and altitudes 25 times higher than any passenger jet. A narrow belt-like band surrounds part of the underside close to the rear—all we see of the engines.

This is the X-30, America's bid to fulfill the long-cherished dream of turning space flight into something as routine as flying cross-country. The "National Aerospace Plane," as the X-30 also is called, is built to zoom directly into space from a runway, orbit the Earth and return for a smooth touchdown, ready to fly again.

But on its first test flight, in 1994, it does no such thing. As the pilot works his engine controls, a spear of nearly colorless flame stabs out the back. The plane accelerates rapidly, but then the sound and fire die out as the X-30 brakes to a stop on the long runway. This is a taxi test, the most basic kind for any aircraft. After several such tests will come the first flight, which will simply circle the runway and land again. It will take dozens of flights and two years of testing before the pilots point that long nose skyward, climbing at an angle far steeper than that of any airliner, on a direct ascent into space. And when the X-30 reaches orbit, it will mark the beginning of the post-shuttle era of spaceflight.

That era will be open to a number of nations, whose engineers are now addressing a fundamental question: What combination of technologies will give the lowest-cost and most effective space transportation? The space shuttle uses rockets only, but rockets are limited in performance, making the shuttle difficult and expensive to operate.

The National Aerospace Plane project, by contrast, pushes technology to the limit by building the most advanced airplane designers can conceive. Its engines cannot be tested properly even in the highest-speed wind tunnels. Its aerodynamic shapes will be determined by the world's most powerful supercomputers, and it will be made of materials only slightly past the laboratory stage.

And for all this, the X-30 won't even be the prototype of an operational craft. Instead, it will prove out technologies for a follow-on project, which will lead to operational spaceplanes after the year 2000.

Other nations' vehicles may fly earlier than the X-30's successor by relying on rocket-like engines with just enough new technology added to make them less costly than the shuttle. Germany's proposed two-stage Saenger spaceplane is such a hybrid; a prototype could make its first demonstration flights by the end of the century. According to current plans, Saenger's first stage would then be modified for use in a super-fast passenger-carrying airliner sometime after 2000.

Japan and Britain (whose Hotol, or "Horizontal Takeoff and Landing" spaceplane, is now being pursued entirely with private funds) both are developing "air-breathing" rocket engines, which gulp air from the atmosphere in the early part of a flight, reducing the need to carry fuel. The Japanese have announced ambitious plans for an aerospace plane similar to the American version, with a projected first flight in 2006.

But the X-30 is likely to be the world's first true spaceplane, the one that will show the way for all others to come.

—T.A. Heppenheimer

Exploring Jupiter's mini-"Solar System".

1995

Galileo Returns to Jupiter

The first major outpost in the vast realm known as the outer Solar System is the "gas giant" Jupiter, orbiting at a mean distance of 482 million miles from the Sun. Jupiter isn't just a single large planet; it's the master of a

THE NEXT TEN YEARS IN SPACE

1991

First in-space tests of Tethered Satellite System for deploying and retrieving satellites on a 60-mile-long wire "tether"

First in a series of International Microgravity Laboratory Spacelab/shuttle missions to study materials and life sciences

First "Spacehab" commercial facility provides added laboratory space in shuttle cargo bay for paying customers

Upper Atmosphere Research Satellite launched by shuttle to begin long-term study of Earth's atmosphere and climatic effects

Jupiter-bound Galileo spacecraft has close encounter with asteroid Gaspra

Planned first demonstration of World Space Foundation's privately funded "solar sail" in orbit

1992

International Space Year begins, coordinating worldwide projects such as "Mission to Planet Earth"

First launch of NASA's new space shuttle orbiter

Japan's home-grown H-2 rocket makes first test flight

First Industrial Space Facility–a commercially developed free-flying laboratory for space experiments–reaches orbit

Japanese "Geotail" and NASA "Wind" spacecraft kick off international program to study solar-terrestrial physics

Mars Observer spacecraft launched toward the Red Planet atop Titan booster

NASA Search for Extraterrestrial Intelligence (SETI) program scheduled to begin advanced search for "alien" radio signals

complex "miniature solar system" of four large moons, at least twelve smaller satellites, a band of icy rings and a powerful magnetic field that influences an immense region of space filled with electrically charged particles.

Four previous reconnaissance missions—two Pioneer spacecraft and two Voyagers—gave us many new details about the Jupiter system, but these quick fly-bys couldn't provide the in-depth, long-term measurements needed to resolve some basic questions. Nor could they focus on the many new questions their discoveries raised.

Galileo will. The Galileo mission to Jupiter, set for launch in October 1989, is by far the most sophisticated and thorough expedition ever sent to the outer Solar System. It consists of a probe, which will penetrate deep into Jupiter's turbulent atmosphere, and an orbiter vehicle that will study the planet, its magnetic domain and its four major satellites—Io, Callisto, Ganymede and Europa—for nearly two years.

Since the Jupiter system in some ways resembles the early Solar System, Galileo may help us understand what happened when the planets began to form about 4.6 billion years ago. Most important is the opportunity to study Jupiter over *time*. Scientists will have the luxury of investigating questions as they occur, rather than waiting years for the arrival of another spacecraft.

Galileo will be launched from the shuttle in Earth orbit. Because its attached Inertial Upper Stage rocket lacks the energy for a direct boost to Jupiter, "gravity assists" from Venus (in February 1990) and from Earth itself will be used to give the spacecraft enough energy to reach its destination.

Following the Venus fly-by and first pass of Earth, Galileo will be in a looping solar orbit that will take it past the asteroid Gaspra in October 1991, for our first close investigation of one of these small bodies. After a second Earth encounter (in December 1992), the spacecraft will finally have gained enough energy to send it toward its rendezvous with Jupiter in December 1995.

One hundred and fifty days before arrival, the probe will separate from the orbiter and head straight for the giant planet. The orbiter's path will then be adjusted so that it can receive and relay data from the probe's seven scientific instruments during the hour or so that they'll be inside Jupiter's atmosphere.

About four hours before closest approach, the orbiter will pass the volcanic moon Io at a distance of about 600 miles. Shortly afterward, the probe will plunge into Jupiter's swirling clouds, taking data on temperature, pressure and chemical composition before its signal is lost in the crushing atmosphere.

With the probe experiment ended, the orbiter will ease into a long, looping orbit around Jupiter. During the next 22 months it will circle the planet ten times, making a close approach to one of the four large moons during each orbit, and studying the entire Jupiter system in much greater detail than ever before. On each orbit, gravitational tugs from the satellites will adjust the spacecraft's flight path.

Galileo's advanced cameras, spectrometers and other instruments will greatly improve our knowledge of the Jupiter system, while returning a "bonus" of data on Venus, the Earth and Moon, and the asteroids. What this two-year expedition tells us about one "miniature solar system" should also advance immeasurably our understanding of the formation and evolution of planetary systems in general.

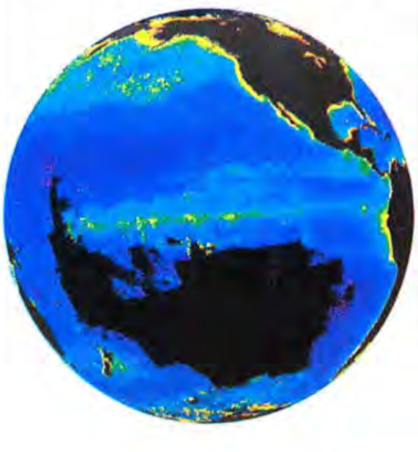
—*Clayne M. Yeates*

1996

Mission to Planet Earth

The headlines tell only part of the story. A thinning of the Earth's ozone layer over Antarctica. Rising carbon dioxide levels in the atmosphere. Massive deforestation in tropical areas. In the late twentieth century, we humans are changing our environment, perhaps irreversibly, in ways that we don't yet fully understand.

Sometime during the fall of 1996, a Titan 4 launch vehicle will lift off from a launch pad in California, carrying with it the largest civilian satellite ever placed by the United States into polar orbit. A few months later, another, smaller satellite will be launched on top of an Ariane booster from the European Space Agency's base in French Guiana.



These two spacecraft—the NASA Polar Orbiting Platform 1 and ESA's Polar Orbiting Platform—will kick off "Mission to Planet Earth," an exciting new era of Earth observation from space. If the rest of the program is approved, they'll be joined within five years by two more polar orbiters and five research satellites in high geostationary orbit. Other satellites, like the planned Tropical Rainfall Monitoring Mission, would also be part of this comprehensive study of our home planet.

We've sent weather satellites and Earth-viewing sensors into space for decades—how is Mission to Planet Earth different? A long-term international program, it will run for fifteen years; some coordination of data and projects has already begun. The mission's strategy is to use a fleet of satellites with a wide range of instruments to study the Earth *as a whole*—in much the same way that spacecraft have explored other planets in the Solar System, but in much greater detail.

Mission to Planet Earth will study the oceans, the land, the polar regions and the atmosphere so that scientists can learn more about the complex relationships that make up the overall global system. The goal is to establish a "baseline" against which changes in that system can be measured, and to develop the ability to predict future changes.

A new generation of advanced remote sensing technology is being developed to help carry out this learning process. Each of the two polar platforms—large, raft-like satellites with room for mounting many different sensors—will have a total mass of about 26,000 pounds. Each one will carry up to twenty scientific instruments, and will be capable of "seeing" more of the spectrum than any previous Earth-viewing satellites.

These will be the most sophisticated and capable civilian remote sensing spacecraft ever flown. The development of new technology for Mission to Planet Earth isn't restricted to the satellites, however. Instruments on the platforms will produce unprecedented amounts of data, and a large part of the challenge is to develop a data handling and distribution system so that scien-

tists all over the world can have access to the information that floods in from space.

Given its global scope, Mission to Planet Earth is likely to have the most participants of any international space project ever. Europe and Japan are contributing spacecraft and instruments, and scientists all over the world will be involved in ground-based measurement and analysis.

As far as we know, the Earth, with its water and its biology, is unique. We live in it, we depend on it—and we have the power to alter it. NASA Administrator James Fletcher neatly summarized the great value of Mission to Planet Earth when he said, "Humankind is now a critical part of Earth's system, and it's clear we've still got a lot to learn about how to be a constructive part of that system." *—Peter Backlund*

1 9 9 6

Space Station Freedom

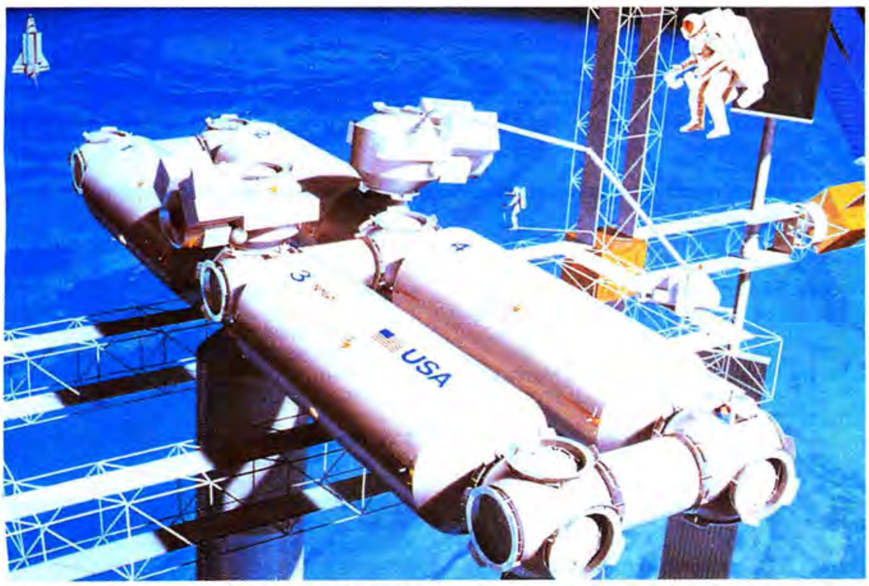
For all our great accomplishments in space over the last 30 years, we've only begun to tap its real potential. We've been visitors to Earth orbit, not residents, and that part-time status has severely limited our ability to reap the harvest of benefits that space affords.

In 1996, we will establish a permanent human presence in orbit with the activation of a fully-equipped international space station called Freedom.

"Human presence"—those are key words. Automated satellites are marvels of technology, but they are simply machines, and no machine has yet been invented that can match human perception, logic, dexterity and creativity. Space station Freedom will permit scientists themselves to conduct experiments in orbit, instead of entrusting their work to remotely operated machines. Whereas the space shuttle can stay in orbit for only about ten days at a time, the station offers a permanently occupied laboratory with an abundance of electrical power. Freedom's solar arrays will produce 75 kilowatts of power in their initial configuration, more later. That compares to only 21 kilowatts for the shuttle, two-thirds of which is used up by the spaceplane's own systems.

Aside from its "habitation module"—which includes a kitchen, shower and enough bunk space for eight people—the station will have three large laboratory modules supplied by the United States, Europe and Japan, each one bigger than a transit bus. Scientific instruments also will be attached to the station's large supporting mast, while another free-flying, human-tended pressurized laboratory will be in a nearby orbit that can be reached from the station. The combined accommodations of the Freedom complex—which also includes two "platforms" of instruments in orbit around the Earth's poles—are equivalent to a large fleet of satellites.

Space Station Freedom will provide a "hands-on" research environment



Opposite: Ocean chlorophyll distribution as seen from space. Above: Space station Freedom, a permanent outpost in orbit

THE NEXT TEN YEARS IN SPACE

1 9 9 3

Mars Observer arrives in Martian orbit to begin two-year investigation of planet's surface chemistry and atmosphere

First test flight of Orbital Maneuvering Vehicle, a space "tug" for moving satellites around in space

Planned first launch of India's new Space Launch Vehicle into a polar orbit

Proposed Soviet mission to map the Moon's surface from lunar orbit

1 9 9 4

Planned first tests of X-30 prototype vehicle for the U.S. National Aerospace Plane

Gravity Probe B, an experiment to test Einstein's theory of relativity, launched into Earth orbit

Soviet "Mars 1994" mission launched, with lander/rover vehicle and French balloon experiment onboard

Soviet space shuttle achieves full operational status by carrying cosmonaut crews and cargo to orbit (early to mid-1990s)

1 9 9 5

Assembly of NASA/international space station Freedom begins in Earth orbit; U.S. laboratory module allows "human-tended" experiments by end of year

Advanced X-Ray Astrophysics Facility launched as the third of NASA's "Great Observatories" in Earth orbit

Europe's advanced Ariane 5 launch vehicle makes first test flight from new launch pad in French Guiana

Galileo arrives at Jupiter, starts two-year intensive study of the giant planet and moons

NASA's proposed Comet Rendezvous/Asteroid Flyby (CRAF) mission heads toward a rendezvous with Comet Kopff in 2000

U.S. Lunar Observer begins investigating Moon's surface from lunar polar orbit (proposed mission for mid- to late-1990s)

that can't be matched in any Earth facility: near- zero gravity, near-perfect vacuum and a vantage point for looking "down" at Earth or "out" to study the universe free of atmospheric distortions.

For the near term, it will serve as a laboratory for advancing basic science and technology; monitoring Earth's resources; solar and galactic astronomy; and medical research.

As the station evolves, it will become an orbiting port where satellites can be brought for servicing, repair and relaunching. Freedom will provide a construction base for assembling space structures too large for the shuttle to carry in one trip, and may also serve as a depot for storing payloads and garaging the space tugs that will travel between low and high Earth orbit. And when humans begin heading out for the Moon and other planets, Freedom will be their way station, like the base camp for a mountain climb.

The space station—now scheduled to begin construction in orbit in 1995—represents a highly visible opportunity for the United States to demonstrate renewed space leadership, while at the same time entering into a multinational partnership of unparalleled scope.

The station is not, in itself, a goal; rather, it is a stepping stone that will make possible the dramatic voyages of exploration contemplated for the 21st century. —*Don Fuqua*

1998

A New Super-Booster

In November 1967, America watched its first, and so far only, "heavy lift" launch vehicle, the Saturn 5, roar into space. Built to carry about 100 tons of payload into low Earth orbit, the Saturn 5 sent astronauts to the Moon and launched our first space station, Skylab, in 1973.

And then—nothing. When NASA decided to develop the space shuttle, it abandoned the Saturn 5 altogether. Today the shuttle, America's largest existing launcher, carries less than one-quarter of Saturn 5's payload. The Air Force's new Titan 4 has only one-fifth of Saturn's lift capacity.

Most experts agree that if the United States expects to send people to Mars or to place a large number of massive scientific or military payloads into orbit, it will have to develop a new heavy-lift vehicle. Any new launcher also will have to cost less and be more reliable than our current fleet.


GENERAL DYNAMICS

The ALS: More lift, less cost.

That's just what the Air Force/NASA Advanced Launch System (ALS) Program was set up to create—a reliable, low-cost heavy-lift booster. Because the nation's current throwaway rockets trace their origins to the missiles that launch nuclear warheads from silos and submarines, they were designed to provide high performance in a minimum package. Cost was secondary. The ALS goal, however, is to reduce the cost of a space launch from about $3,000 to $300 per pound.

In order to cut costs to the bone, ALS program managers are starting with a "clean sheet of paper" and looking at the entire launch process—manufacture, launch operations and spacecraft deployment—for potential reductions. The program's managers hope to take advantage of new advances in computer technology and information processing, including computer integrated manufacturing, paperless management and artificial intelligence for launch preparation.

For now, the ALS program is still in the study and test phase; no one has begun yet to build hardware. If future military and civilian requirements mandate a heavy-lift launch vehicle, ALS managers say they can test the first copy by 1998. Because it's looking for flexibility, the ALS team is working on a whole range of "space trucks" to carry payloads weighing from 40 to 100 tons.

The ALS program is even taking aim at the high cost of space cargo itself. Current boosters severely restrict the weight of the payloads they carry into orbit, causing engineers to use expensive manufacturing techniques to come in under weight; some spacecraft cost as much as $60,000 *per pound*. ALS managers figure that a cheap superbooster will relax these restrictions and lead to much less expensive spacecraft.

But the ability of the ALS program to meet its cost goals depends directly on a high demand for launch services. If the government's civilian and military space programs continue at their current moderate pace, and if private demand for launch services fails to increase markedly, there will be little need for an Advanced Launch System.

In that event, some NASA officials argue, the United States might be better served by building the heavy launcher that NASA has proposed. Dubbed "Shuttle-C" (for cargo), the concept is based on shuttle technology, and could carry 40 to 75 tons into low Earth orbit. Because Shuttle-C uses relatively expensive technology and launch operations, it would be much more costly than the ALS.

It also would be a lot cheaper to develop, however, and might be ready four to five years earlier. Further, the risk of Shuttle-C exceeding its cost and schedule estimates is much lower than with the untried ALS, which would push the state of the art in launch design.

—*Ray A. Williamson*

Contributors

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Don Fuqua is president of the Aerospace Industries Association, and was formerly

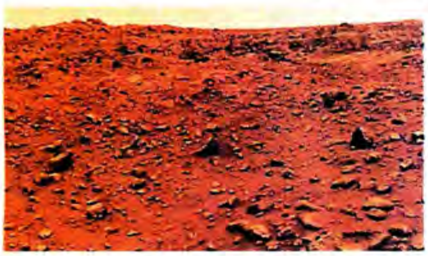
1 9 9 8

Returning Samples of Mars

Has life ever existed on Mars? How difficult will it be to send people to its surface and return them safely to Earth? Are there resources on the Red Planet that we can use to sustain a human presence? These are among the questions that await the outcome of a Mars Rover/Sample Return mission, currently on NASA's drawing board for the end of this century.

Mars has always fascinated mankind—its reddish color and periodic brightening make it particularly distinctive in the night sky. But it was the Martian "canals" that stimulated the human imagination most; earlier this century, many people believed they were clear evidence of civilization.

We know now, of course, that the canals were imaginary, yet our fascination with Mars continues. We've learned from spacecraft observations that it's an extraordinary planet, a geological wonderland with huge volcanoes, deep canyons and enormous dry river beds. And while the present climate is rather forbidding and inhospitable to life, in the distant past—when life began on Earth—conditions on our home planet and Mars were very similar. Did life originate on Mars, then fail as climatic conditions changed? One way to find out is to go there, collect samples and return them for analysis.



The main interest in sending robots to bring back pieces of Mars, however, is to pave the way for human exploration. Inevitably, Mars will be the first planet beyond the Earth to be visited by humans. Before we embark on this journey, we'll want to test the necessary technology with unmanned robots. We'll need to practice rendezvous maneuvers in Mars orbit as well as techniques for "aerobraking" spacecraft in the atmosphere, and we'll need to gain experience in moving around on the surface.

We'll also need to know if Mars presents hazards to humans. We've learned from the Viking spacecraft that the Martian soil, unlike that on the Moon, is chemically reactive. What materials should we use in life support systems—spacesuits, for example— to ensure the safety of the first explorers?

Several ways of doing a Mars Rover/Sample Return mission are being studied. With the launch vehicles currently in development, two launches would be required: one for the rover, another for the ascent vehicle that will lift the samples off the Martian surface.

Most likely, the rover will touch down first. It will wander across the surface, testing the ability to travel on Mars, examining the terrain, analyzing accessible materials with a variety of instruments and collecting samples.

Some time afterward, the ascent vehicle will land next to the rover (possibly guided by a beacon), and the rover will deliver its samples to the ascent vehicle. After liftoff from Mars, the sample carrier will rendezvous with an Earth-return vehicle circling in Mars orbit and transfer the Martian materials for launch back to Earth. The rover, left on the surface, will continue its exploration.

A mission this complex presents many technical challenges. Radio signals take as long as 20 minutes to get from Earth to Mars, effectively ruling out interactive human control. Tasks such as driving around on the surface, picking up samples, performing on-the-spot analyses and rendezvousing in Mars orbit will need to be automated, subject to only occasional commands from Earth.

Nevertheless, we believe we can overcome the technical obstacles. By the end of the century, we should have the first pieces of another planet in our hands, which will set the stage for more ambitious human expeditions to Mars in the next century. —*Michael H. Carr*

Chairman of the House Science and Technology Committee.

Ray A. Williamson is a senior associate at the Congressional Office of Technology Assessment, and a contributor to two OTA reports on which this article is partly based: *Launch Options for the Future: A Buyer's Guide,* and *Reducing Launch Operations Costs: New Technologies and Practices.*

Michael H. Carr is a geologist with the U.S. Geological Survey in Menlo Park, California, and chairman of the Science Working Group for the Mars Rover/Sample Return Mission.

THE NEXT TEN YEARS IN SPACE

1 9 9 6

Attachment of "habitability" module to space station Freedom allows orbiting base to be permanently occupied

U.S. and European remote sensing "platforms" launched into polar orbit as part of "Mission to Planet Earth"

NASDA

Japanese HOPE (H-2 Orbiting Plane) unpiloted mini-shuttle makes first test flight atop H-2 booster

Planned launch of Vesta, a European/French/Soviet mission to study several different comets and asteroids

Proposed launch of U.S./European Cassini mission to explore Saturn and its moon Titan

1 9 9 7

Japanese Experiment Module and European "Columbus" laboratory module attached to space station Freedom

Soviet advanced "Mir 2" space station becomes operational in Earth orbit (mid-to- late 1990s)

1 9 9 8

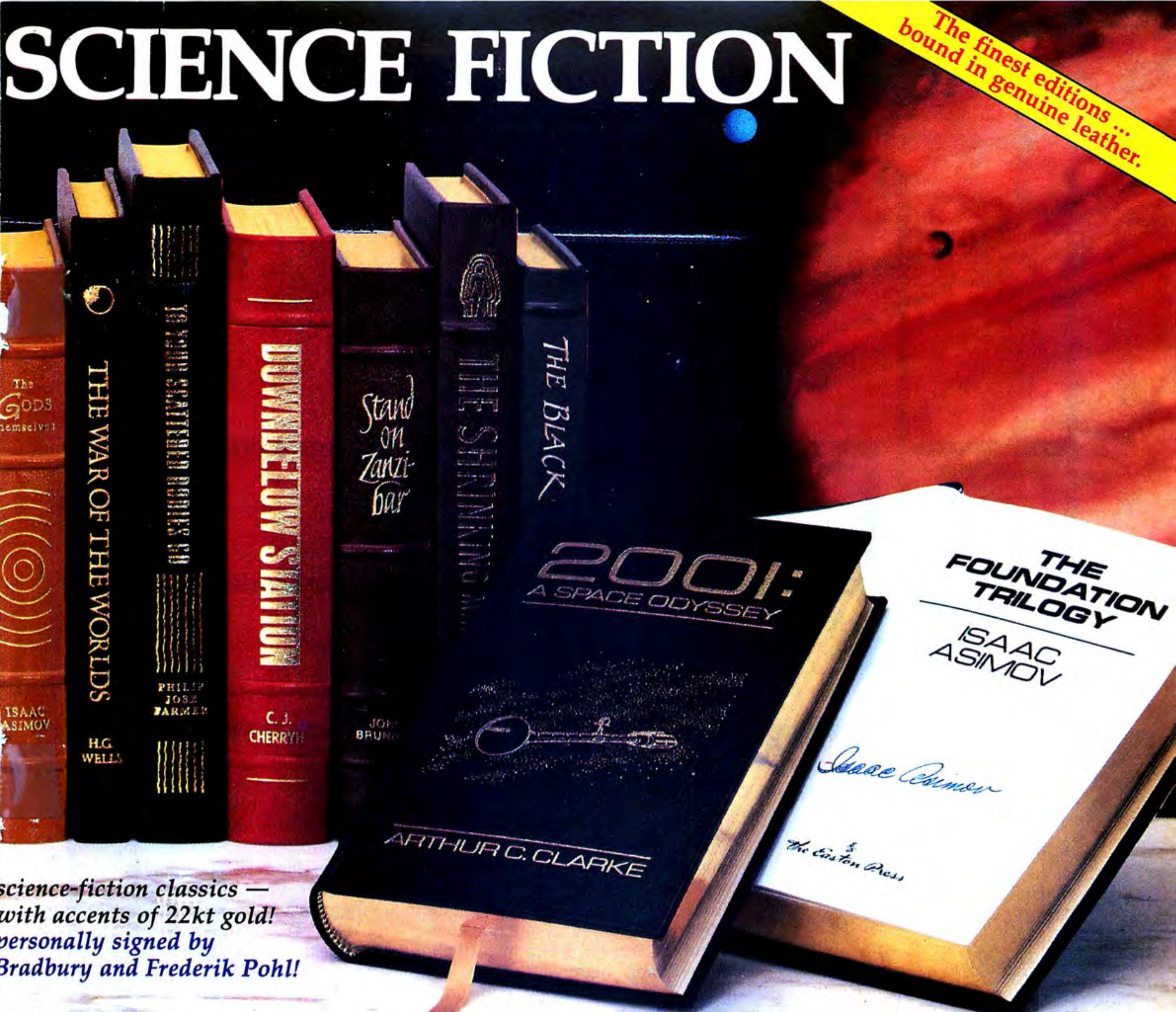
Space shuttle crews complete assembly of space station Freedom in Earth orbit

Mars Rover/Sample Return mission launched to gather samples of Martian rock and soil and return them to Earth

Europe's Man-Tended Free-Flyer launched as a small orbiting laboratory associated with space station Freedom

Proposed first test of U.S. Advanced Launch System "heavy lift" rocket for military and civilian use

First test flight of French Hermes mini-shuttle on an Ariane 5 booster, in unpiloted mode



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HERMES

Built in France, named for a Greek god, launched in South America, this mini-shuttle promises to put Europe in the manned spaceflight business by the millennium.

BY ROBERT M. POWERS

Sunrise over the Atlantic, December 5, 2000...

As the Sun line sweeps onto the northeast coast of South America, the blue dawn and intensely humid tropical night soften into day at the European Space Agency's launch center in Kourou, French Guiana. Accompanied by a swarm of technicians, three astronauts—one each from France, Germany and Italy—make the long walk to the waiting Hermes spaceplane, which sits atop a fuming Ariane booster rocket. They are bound for the NASA/international space station. They will be gone from Earth for half a year.

About three miles away, the "Le Toucan" observation pavilion at Kourou is filled with journalists from all over the world. Locals call it a *carbet,* the equivalent of a Guianan collective hut. Le Toucan used to be a makeshift cabin; it is now a huge circular room, filled with a dozen monitor screens, courtesy of the public relations people.

The countdown reaches T minus two minutes. No matter how many times you see a launch there is magic about it. The memory of having dreamed, and dreamed of the moment when we leave the Earth for somewhere else, must lie very deeply buried; it is not a logical feeling or even a straightforward subconscious one. It's back in the mists of some prehistory, but you feel it anyway.

Across the pads and far into the lurking jungle, the press announcer's voice booms the final seconds: *"trois... deux ...un... Feu!"* Heavy vibration and rumble. And then bang! Ariane/Hermes lifts off the pad. Thirty seconds later, roaring past the speed of sound, the rocket is only a high-flying dot trailed by a disappearing plume of exhaust smoke.

Here in steamy French Guiana, one onlooker wonders aloud if, in some unfathomable way, the soul of Wilfried de Fonvielle is watching. At the age of eleven, the intrepid French boy offered to ride Claud Ruggieri's rocket a century and a half ago; Claud had been launching small animals to low altitudes and returning them to Earth via parachute. Alas, young Wilfried, the first astronaut-in-training, never got his chance; the French police put a stop to the experiment.

It is hardly a surprise that Europe has been developing a strong space program all along, but now the European Space Agency (ESA) has entered a new arena; it has kicked on the afterburners for a well-designed and highly capable manned effort centered on the Ariane 5 launcher and the Hermes spaceplane.

The whole manned spaceflight package—Ariane 5, Hermes, the Columbus orbiting laboratory and data relay satellites to help the system func-

ALL ART AND PHOTOS: EUROPEAN SPACE AGENCY

The European view is that the 21st century will be the century of space development, and they have no interest in being left behind or taking a back seat to anyone.

tion—is incredibly cheap; each European taxpayer will be contributing about ten dollars a year to the manned space program by 1993, a fraction of what the Soviet civilian space program costs and far, far less than the American or Chinese space programs.

The European manned space effort is a massive combination of talent, money, a complex but very cohesive political mix, and a driving energy that is very reminiscent of the halcyon days at NASA before and after the lunar landing.

The heavy-lift Ariane 5, which will eventually be able to boost about 21 metric tons into a 300-mile-high orbit, is a derivative of France's successful Ariane series of launchers. It and the Hermes spaceplane are funded primarily by France, Germany and Italy, with help from Belgium, Austria, Denmark, the Netherlands, Spain, Norway, Switzerland, Sweden and even Ireland. (The British, citing serious misgivings about the long-term payback of such an ambitious program, have refused to fund anything but a small portion of the Columbus space station module.)

The European nations, through ESA, have expressed a near-unanimous political will to secure a complete, coherent and balanced space program. The European view is that the 21st century will be the century of space development, and they have no interest in being left behind or taking a back seat to anyone.

Headed by Professor Reimar Luest, ESA has had extraordinary support from France's minister of research Alain Madelin, and Frederic d'Allest, director of the French space agency CNES. None of these three top leaders of European space has been in the least naive about what it will take to do what they plan: *"les moyens de l'ambition"*—ambition means investment.

The ideas and basic designs for the Hermes spaceplane have existed in France for more than twelve years. A full scale mockup was presented at the Paris Air Show in 1985, the same year that ESA finally threw the switch to design, test and fly Hermes into space. Development of the Ariane 5/Hermes combination was formalized during a major meeting of ESA member nations in November 1987, a gathering which also mapped out European space plans through the millennium.

For three years, the spaceplane has been under continuous study by engineers at the French company Aerospatiale, the project's lead industrial contractor. Since last April, they have been working hard on "phase 1" of Hermes, which will end in 1990. If all goes well, ESA will give the green light to "phase 2": construction of two spaceworthy vehicles.

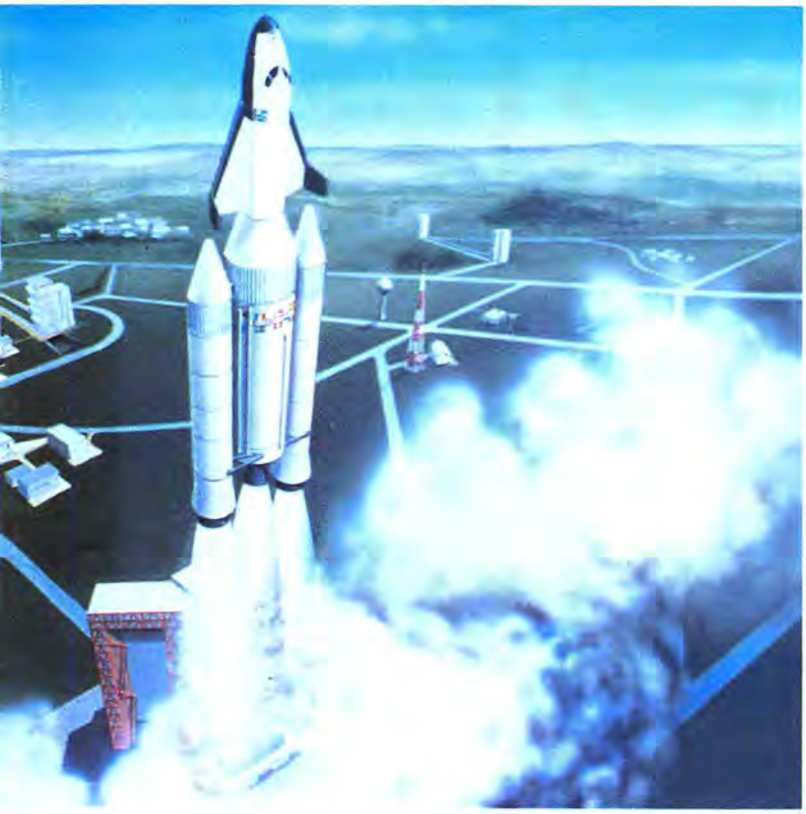
A first launch (unmanned) is penciled in for summer 1998, with astronauts to climb aboard in early 1999. It's a timetable that may, if anything, be somewhat conservative.

One of the program's main objectives is to service ESA's Man-Tended Free Flyer (MTFF) orbital platform during six-day missions. But Hermes also will be able to rendezvous and dock with planned and existing Soviet and American space stations, and with the Columbus pressurized module. It will make two flights annually and have an operational lifetime of about 15 years. And it can be used for rescue of either Soviet or American astronauts, if that's what everyone agrees to.

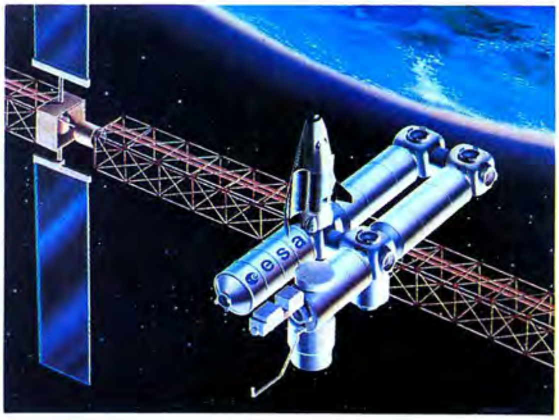
According to Bernard Deloffre of Aerospatiale, who has been associated with space programs and space engineering for a quarter-century, the design of Hermes both directly and indirectly involves the American space shuttle.

The direct involvement has to do with the docking mechanism NASA proposes for the international space station. It is sized for the American shuttle (Philippe Couillard, director of manned spaceflight at CNES candidly calls the mechanism "unwieldy, heavy and a monster"), so some compromise solution is needed.

Since Hermes may also link up with the Mir space complex, the docking adapter design must be worked out with the Soviets as well. "We have not to date received clear specifications as to how the docking plate will be constructed for the Soviet station," says Deloffre. "It is a difficulty for us today as



Launched on top of an Ariane 5 booster, Hermes will be able to carry crews to a space station (below) or dock with a "Man-Tended Free-Flyer" automated laboratory in orbit (left).



we try to finalize the Hermes design.

"But our primary mission," he adds, "is to dock with the MTFF, and reach the attached pressurized module which is the European part of the international space station. Within those performance guidelines, if we are also able to attach to the other space stations, it would be nice."

A less direct American influence on the Hermes design resulted from the Challenger accident, even though Deloffre and the other engineers at Aerospatiale had been working on the problem of crew safety long before January 1986.

"We had designed an extractor stage located in the adapter between Hermes and the launch vehicle," he says. "The Challenger disaster focused everyone's attention on crew safety. We realized that the extractor concept had a drawback: it assumed that the spaceplane was intact, wings and everything. In an accident this might be so—and it might not."

The present plan to incorporate an ejectable escape capsule is quite different from any Soviet or American concepts. It is designed to be used at any time during the first two minutes of flight (up to Mach 7 and around 30 miles altitude), and it can also be used during re-entry within the same limits.

There is considerable argument among the European astronauts over the need for an escape capsule, but French *spationaute* Patrick Baudry, who has both flown in the U.S. space shuttle and trained in the Soviet program (see page 38), simply says that "no spacecraft is ever completely safe. We are basically test pilots; we know the risks."

Germany's Ernst Messerschmid, who spent seven days in orbit during a shuttle/Spacelab mission three years ago, remarks that the additional weight of the escape module eliminates "one astronaut and part of the payload capacity." His Spacelab partner Rheinhard Furrer echoes Baudry: "We are taking risks. We do so with our eyes open."

Despite the negative comments by the astronauts who potentially will fly Hermes, the crew escape capsule is presently a fixed part of the spaceplane program. Aerospatiale's Deloffre points out that studies have shown three astronauts can do all the tasks required, so it is not just the weight of the escape module that has reduced crew size from the four that originally were planned.

"And for another thing," adds Philippe Couillard of CNES, "the public would never forgive us for making the same mistake as the Americans ten or twelve years later!"

Aerospatiale engineers are now concentrating on developing a successful Hermes design, but they also are considering the 21st century with wide open eyes and ideas. "We are looking at horizontal take-off launchers for future generations of Hermes," Deloffre explains. "And while we don't want to duplicate things that are done somewhere else—if the USA operates a vehicle like the orbiter, why would we develop something which performs the same types of missions —we can develop something which is complementary for the future."

However brilliantly designed, Hermes will be of little use without the Ariane 5 booster rocket, which differs totally from its forerunners. In three different configurations, it will enable Europe to launch satellites into high orbits, lift hefty space station components and carry Europeans into space aboard Hermes.

"Compared with our role for previous Ariane versions, we are in a fresh dimension," says Pierre Lacau, director of launcher programs for Aerospatiale. "Ariane 5 is expected to carry extremely expensive hardware into space. Its reliability must be improved by an order of magnitude over any previous Ariane....after all, it will carry Hermes. It is a much more sophisticated and complex design because of this. It is very difficult."

The philosophy behind the development of the Ariane 5 also is important. "Looking at the American shuttle program," says Lacau, "you see a very complicated system. It costs a lot of money to launch a shuttle with six or seven astronauts on a week-long

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PATRICK BAUDRY

Of the 200 people or so who've flown in space, only one has been "inside" both the Soviet and U.S. programs: Patrick Baudry, a French test pilot who flew as a guest astronaut on shuttle mission 51-G in 1985, after having trained as a backup for fellow countryman Jean-Loup Chretien's fight onboard the Soviet Salyut 7 space station in 1982.

Today the 42 year-old Baudry heads the development effort for Europe's planned Hermes spaceplane (see page 34). Recently, contributing editor Robert M. Powers caught up with the "spationaute" during one of his frequent trips to Houston.

Final Frontier: You've trained both with the Soviets in Star Town and, of course, in Houston with the American space program. Jean-Loup Chretien said, sometime back, that he felt he was being treated more or less as a passenger by the Soviets. Someone else told me a terrible story about how you and Chretien had been left at the NASA gate for a whole day the first time you went there. Can you give us a brief personal description of the differences you see in training for the two space programs?

Baudry: It's difficult [to say]. In fact, Jean-Loup did not train in Houston, because NASA trains only the crew, and Chretien was not part of the crew. So he didn't get any training.

From my point of view, I think in Houston you have the best of what you can imagine in the space business. The space shuttle, to me, is an extraordinary vehicle, certainly the best space vehicle ever built. So I have a great respect for the people here working on this system.

A French astronaut talks about the Americans, the Soviets and the proper wine for space travel.

But it's true that when we came, we were not particularly welcomed. At NASA there are two tendencies: one which says the [shuttle] is an American spacecraft, so it's not normal to give a place to somebody else, and the other tendency, which says, "okay, we have a beautiful spacecraft, and it's a good thing we can share a bit of it with other countries."

But you don't have to judge the whole [NASA] community because part of it had bad behavior. I spent a year [in the United States]. I have very good friends. I made a beautiful flight—all sorts of experiments—and it worked perfectly.

The difference is that the shuttle is a vehicle with five-, six- or seven-member crews. And the Soyuz and Hermes have only three-member crews. So the way of organizing the schedule and the work during launch, ascent, rendezvous, etc., is different, because a three-member crew works in a completely different way from a five- or eight-member crew.

Aboard the shuttle you can have passengers, people who don't have any task related directly to the shuttle system. That's the first time in space history.

Final Frontier: Does the training itself differ greatly between the Soviet space program and the American?

Baudry: In fact, the concentration for a flight is the same for the crew in Houston as in Star City. But there are some differences. In Russia you have much more physical training than in Houston. The American astronauts organize their physical training themselves, but in Star City we had a lot of

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TASS/SOVFOTO

BAUDRY

SPATIONAUTE

Inside launch control, Discovery's return to space was not just an adventure. It was a job.

By Dennis Chamberland

"We Have Liftoff!"

September 29, 1988, 3 a.m. As a new launch team member, I feel like I'm starting my first game in the Superbowl. Anxious and more than a little self-conscious, I brace myself to participate in one of the most important launches in history: America's return to space after a "down time" of almost three years.

I arrive for duty in Firing Room 2 at the Kennedy Space Center in Florida. My station is the newly-installed Personnel Accountability Console – "PAC" in the eternal acronymic jargon of NASA. For me, the road here has been a long one. Although I'd had my sights on a job with NASA for about eight years, I only joined the Kennedy staff in the summer of 1987, and this will be my first liftoff.

Here in the Launch Control Center are four firing rooms, two of which are used for any given shuttle launch. (This is not to be confused with "Mission Control" in Houston, which takes charge only *after* the shuttle clears the launch tower). Each firing room sports orderly rows of consoles, all linked together by radio hook-up so the members of the launch team can talk to each other.

Inside Firing Room 1 is the Management Team, including the NASA Test Director, who quarterbacks the operation, and astronaut Bob Crippen, now NASA's Deputy Director for Shuttle Operations. When the launch reaches its critical endpoint, at T-minus-9 minutes, it's Crippen alone who will give the final go/no-go decision. My group in Firing Room 2 includes teams responsible for the shuttle's main engines, ice inspection, personnel safety and other systems. Between the two nerve centers, some 350 individuals are at their consoles.

Mindful of "firing room discipline,"

TOM AND MARK USCIAK

my PAC team members and I plug into the network with some apprehension. I half want to offer up a joke to my co-workers just to calm the moment, but I pass up the urge when I notice a firing room veteran from the Gemini days sitting next to me.

The best way to picture what goes on inside the firing room at launch time is to divide the shuttle up into its major components: solid rockets, fuel tank and the orbiter vehicle itself. Then break these up into their major parts, and assign each one a team, a console and an individual radio channel on the net. Most consoles have computers and video monitors for viewing specific parts of the shuttle, weather radar and even gauges in remote places on the launch pad.

My own job is to monitor the whereabouts and safety of all personnel out on the pad who are preparing Discovery for liftoff. Using video monitors and radios, the three of us on the PAC team log the position of everyone on the pad after the shuttle is loaded with hazardous fuels. In an emergency, we must relay the last known positions of all personnel back to the Test Director and to safety and rescue teams. We also track the positions of the astronauts right down to the moment of liftoff.

As I sit at my console in these predawn hours, I can't help but be impressed by the history and astonishing amount of experience all around me. I adjust the volume of my console headset, knowing that veterans of every program from Mercury to the shuttle will be listening. The test team is an exquisitely tuned machine, and mistakes tend not to go unnoticed.

Like a true neophyte, I practice my little setpiece as I dial onto the network. The simple one-liner is supposed to be, "Personnel Accountability Console manned and ready to support." What actually comes out is "ready to *provide service*."

Fortunately, Test Director Frank Merlino, himself a veteran of all previous shuttle launches, had discussed my "freshman" status with me the day before. Ever the professional, Merlino immediately senses my anxiety and smooths the awkward moment with a pleasant "Good morning."

As my team sets about monitoring the launch pad workers, an eerie image appears on one of our color monitors. The crew that looks for dangerous ice formations on the frigid external tank is

Once aloft, Discovery's tourist-astronauts photographed Earth scenery like the Hawaiian Islands.

on the uppermost level of the launch platform. In the glare of the pad lights, a heavy layer of freezing mist from the vehicle and its supercooled tanks swirls around them. As the orange-suited members of the Ice Team penetrate the mist, I remark to someone that this chilling image is more dramatic and compelling than any I've ever seen, even in science fiction.

The countdown continues through the steamy Florida dawn. The astronauts are awake now, having breakfast. Soon they'll board a van for the 20-minute drive to Pad 39B.

The tempo of launch operations starts to pick up. Merlino assigns "working groups," allocating each one a separate channel to discuss their business independently before reporting to the team as a whole. With a little practice, I can switch mentally between these conversations amid the buzz–a peculiar form of active listening. It's during this period that a sense of teamwork, even kinship, emerges. In the firing room, there is absolutely no "me"–it's only the team that has any real meaning.

As the sky lightens, the console operators occasionally stand up to restore circulation, then quickly sit back down. No eating, drinking or smoking is allowed in the firing rooms, so we greet enthusiastically the roll of breath mints someone smuggles down the row at sunrise: breakfast!

The astronauts finally arrive at the pad. Inside Discovery, several close-out technicians are setting and checking switches prior to launch. A member of the close-out crew once confessed that they're sometimes called "GBA's," or Ground Bound Astronauts, because they know the shuttle systems as well as anyone. It's no secret that most of the workers at Kennedy would gladly accept a ride on any shuttle, any time.

This is an interesting way to follow a launch, and it's nothing like the dozens of others I've watched on television. Even with my knowledge of the system and the countdown procedure, I have to filter a lot of information to synthesize the overall view. In the firing room, we have no idea what the world is being told of the launch progress. When high-altitude winds force a countdown "hold," we catch it in bits and pieces as we work at our own stations.

Finally, as we prepare to emerge from the last built-in hold at T-minus-9 minutes, it really hits us: Discovery is going to go! Just before picking up the countdown, quarterback Merlino polls all the major consoles–the management team, engineering, safety and others. In one incredibly brief moment, this vote of the launch team members culminates everything accomplished during the past 32 months of recovery. The work of a whole agency and a presidential commission, endless engineering sessions and a library of documents are sealed in the simple words of the firing room teams: "We are go."

I can see out the firing room's spacious windows that a cloud bank is building over the ocean. I quickly switch one of our idle monitors to the Operational Television System weather circuit. The radar paints an approaching rain storm. I know this *count* probably won't tolerate any additional holds; as the final minutes tick away, I hope that after all we've gone through, Discovery wins its race with the rain.

The count approaches T-minus-60 seconds. Merlino coolly checks off each event mandated by "Sue Seven," the document numbered "S0007" that lists with maddening precision all the procedures that make up a countdown. Any problems now will be handled moment by moment, as time is subdivided into ever smaller fractions by the computers. Soon the machines will take over the count entirely, as the

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The loneliness of the long distance space traveler

DIARY OF A COSMONAUT

By Valentin Lebedev

BILL REYNOLDS

The Salyut 7 space station was still brand new in May 1982, when Soviet cosmonauts Valentin Lebedev and Anatoliy ("Tolia") Berezovoy boarded it to begin an orbital endurance test that was to last more than 200 days. Their record-setting flight included a full schedule of experiments in astrophysics, Earth observation, plant growth and materials processing. The cosmonauts also conducted a spacewalk and played hosts to two different Soyuz "guest" crews. But each time the visitors left, it was just Lebedev and Berezovoy alone again, for seven months in a small room.

Despite regular radio and video "communications sessions" with the Flight Control Center (FCC) and with their families, friends and well-wishers on the ground, the cosmonauts were acutely aware of their struggle to maintain an even balance with their own moods and with each other.

These selections from Lebedev's daily diary, which were recently published for the first time in English, show his great candor and willingness to write "everything just as it happened, as I saw it, as I felt it and understood it."

July 11

We don't understand what's going on with us. We silently walk by each other, feeling offended. We have to find some way to make things better.

Yesterday I struggled the whole day with the *Oazis [*plant growth experiment]. Tolia asked me, "Why are you putting up with this thing? Why don't you just tell the engineers to shove it, if it was made so poorly?"

I replied that it's useless to get on their nerves and try to blame them for things they can't correct now. It would be easier for me to repair it. So I did.

Today I began to doubt my chances of completing the long flight. They say that doubt is the beginning of failure. Maybe, for some people. But for me, to doubt is to search for different ways to succeed....

Today is Fisherman's Day. We received a radio telegram "From the mariners of the northern, southern and far eastern seas. We are sending best wishes to Anatoliy Berezovoy and Valentin Lebedev in conducting the experiments of the World Ocean Research program. We express our thanks to you for all the help you've provided to our fleet.–Deputy Minister Bystrov."

At the end of the day at 10 p.m., we watched the final soccer game of the world championship, Italy vs. West Germany, 3:2....

July 13

I didn't sleep the whole night long. A palpitation. How sensitive I am! I got up earlier than usual and began to unload the resupply ship [a Progress automated spacecraft, which had just docked with the station]. This time it had been loaded properly. I opened a hatch and looked for letters, but there were none from Lusia [Lebedev's wife]. There was only one letter to Tolia, and it was an old letter dated the 28th of

June. I was upset. I was looking forward so much to letters from home. I asked the Ground where they'd put them. They told us that the letters were in the eighth container on the bottom of the resupply ship. They probably loaded it this way on purpose so that we would finish unloading quickly.

We unloaded while listening to music from Earth: "Riabina Kurtchavaya (Leafy Mountain Ash)" and "Rassvetaly Yablony I Grushi (Apples and Pears Were Blooming)." By the end of the day we had finally reached the eighth container and had almost completely unloaded Progress, but there were no letters. We were quite upset. We drank tea and ate apples before going to sleep. Lusia sent us Tula's [a town in Russia] *prianik* (honey-cakes) and had signed each of them with good wishes. We ate some tomatoes and a lemon they'd also sent....

July 22

....During the day, on the TV report, we wished a happy 50th anniversary to the Adigei Autonomous Republic. Tolia was born there. It's amazing how everything turns out in your life: several years ago I had been in the Adigei Republic and stopped in Enem, a small village. I never thought that I would fly into space with a guy from that village.

We worked hard the whole day, but we enjoyed it. In the evening we decided to do some work with the electrophotometer. However, due to the small viewing angle, we couldn't recognize a single star through the view-finder; we cut a piece from the vacuum cleaner tube, attached it to the equipment, and, *voila*! A view-finder!

I exercised a lot on the velo-ergometer [exercise machine], which was on its fifth setting...which is like riding a bicycle up a hill. I perspired a lot. The sweat doesn't drip down, but hangs on my forehead and wiggles like a jellyfish as I move.

Up here we eat apples and tomatoes like on Earth. The station is a mess–bags with pieces of equipment hang in the scientific equipment compartment, the intermediate chamber is packed with regenerators and absorbers; and the resupply ship is also choked with regenerators and EDV containers. Only the connecting compartment looks clean and spacious, with nothing extra scattered about.

Inside of the *Oazis* wheat is growing so fast that you can see it grow. It's so interesting to see how it grows; this is life. Inside the second vessel the pea plants are just beginning to germinate.

A funny thing happened with the onion bulbs which were sent to us for the biological experiment. One week after we were supposed to plant them, a biologist came to the radio session and asked us, "How are the plants doing?"

We answered.

"What about the onions?" he asked.

We told him the onions were growing well. But the truth was, that as we were unloading the resupply ship, we found some rye bread and a sharp knife. How very considerate of them. So we ate some bread. It was wonderful. Then we saw the onion bulbs we were supposed to plant. We couldn't resist; we ate them right there and then, with bread and salt. They were delicious!

Time went by and the biologist asked us again, "How are the onions?"

We always replied, "They are growing."

"Are the sprigs long?"

"Yes, they are," we replied.

Once at the question, "Do they have any shoots yet?" without any hesitation we replied that they even had shoots.

I heard the excitement at the communication station.

Then Tolia whispered to me, "Valentin, the shoots are the flowers of the onion."

Oh, my gosh! One can easily cause a sensation this way. As we know, onions had never bloomed in space before. We asked to have the biologist on-line so we could speak to him in private.

"For God's sake," we told him, "Don't get upset, we ate all your onions."

What could we do? We laughed, and promised him we'd plant the next batch of onion.

Tolia told me that we have to fly for four more months. I looked at him–he became very quiet. He sank in thought. Tomorrow we will have a physical; the doctors will give us a complete check-up before the spacewalk.

July 23

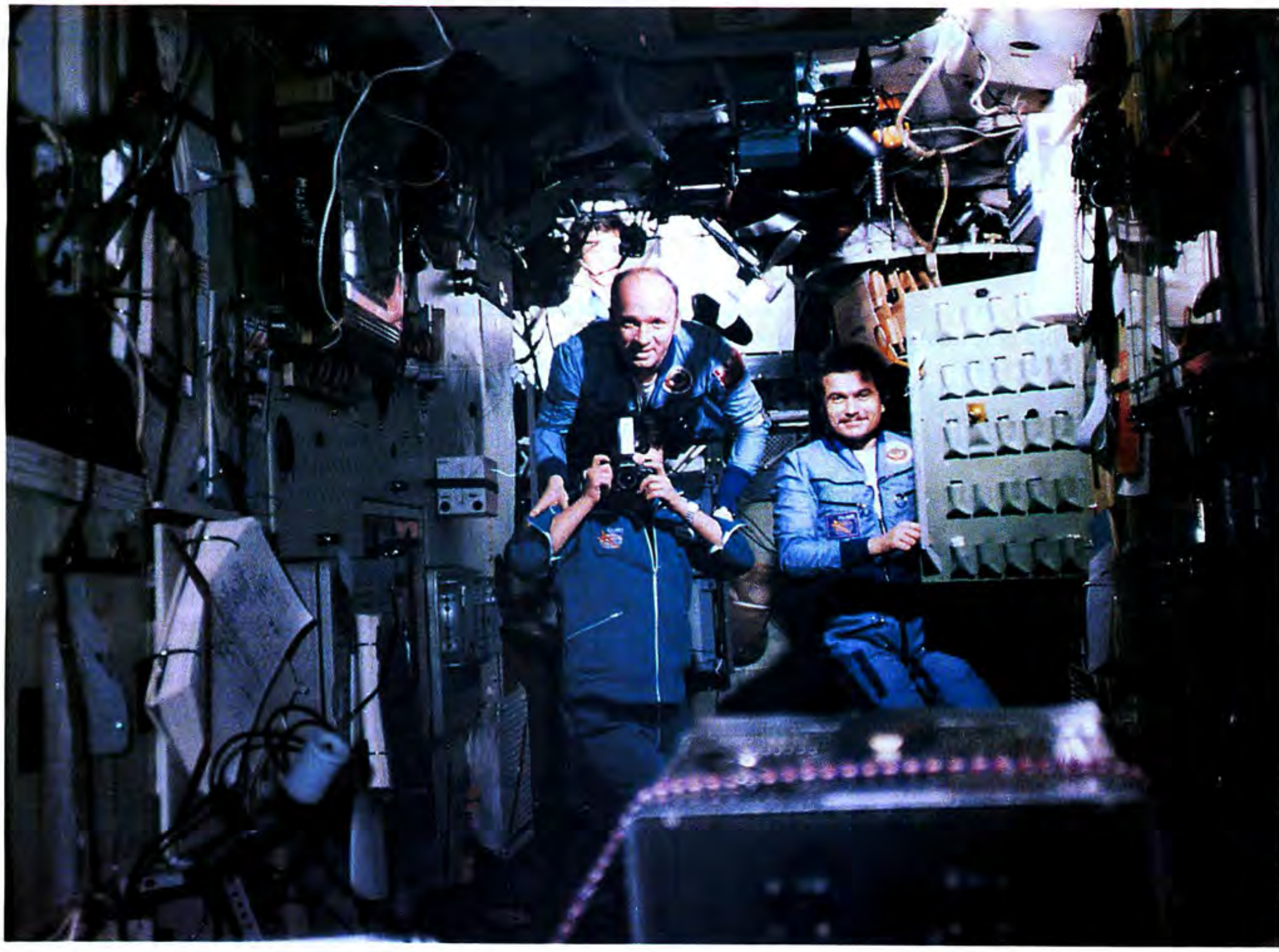
I slept very soundly, and even though it was only for seven hours, I didn't feel sleepy when I woke up. The medical examination began early in the morning. These occasions didn't excite us very much....We have to sit naked, hooked up to electrodes and sensors, among cables and wires, which float like sea weeds, and wait to be put on-line. After the order from the FCC [Flight Control Center], we can warm up by doing exercises on the velo-ergometer, set up with different physical loads.

Sometimes we have to sit in a resting position and provide the ground with all twelve EKG parameters. During all this time we hang in the air, shivering from the chill.

As I mentioned earlier, the hardest part of a prolonged flight is communication with ground control. Every minute we have to keep ourselves in complete control. Different people come on-line to talk to us, and some of them have forgotten that a person in space is always busy working, even when he is asleep. Also, when different people come on-line, they sometimes show their emotions through the tones of their voices and things they say. Therefore, inappropriate words or jokes can put us off balance for an entire day. In general, it is inappropriate for FCC personnel to demonstrate their bad mood to the crew in space.

During our conversation, a radio commentator asked us, "What does a wet cleaning mean on the station?"

"Everybody knows what that means at home," we replied.


ALL PHOTOS: TASS/SOVFOTO

Lebedev (left) and Berezovoy were visited twice during their seven-month stay on the Salyut station (opposite page). Above: one of the visitors, Svetlana Savitskaya, snaps a picture.

In the household, trash collects on the floor, and dust gathers on the furniture. Here everything floats: dust, pieces of trash, crumbs of food, drops of juice, coffee and tea. It all ends up suspended in the station, with most of it collecting on the intake grills of the fans, which we cover with cheesecloth. This way we collect the trash in weightlessness, where everything floats. Then we roll up the cheesecloth napkins and replace them with new ones.

We have to clean our station regularly, for ourselves as well as for our guests, and here's how we do it: we have some wet napkins with katamine, a special detergent with good scouring characteristics. We wipe the panels with the napkins, also the table where we eat and work, hand-rails, bars, door-hatches, surfaces of the control panel and pieces of equipment. Some housewives manage to do this every day, but we do this only once a week.

Once in a while we have to do a major cleaning, during which we vacuum all the hard-to-reach places where trash builds up. To clean them we have to open up all the panels so we can vacuum the bundles of cables, pipes, fan grilles, and the dust-collectors of the gas-liquid heat exchangers.

Sometimes we find things we thought we had lost forever. We were puzzled about how things ended up where they did. To make searching easier, we use a balloon; if something disappears we release the balloon and watch where it goes, and there we look for the lost item....

September 1

We congratulated each other on this very special day for our children, the beginning of the new school year. Yes, it's true that this day is not only an important day for our children but also for us grown-ups. Today I suppose we all remember our childhood and school years. We made a TV broadcast and wished all children a happy September 1....

....Now I'll tell you how we "walk" here on the station. First of all, this word doesn't quite apply here. It is more accurate to say we fly or float from one place to another. We've gotten so used to it that we can fly through the entire station from the assembly compartment to the connecting compartment, without hitting anything, in one stroke....Swimming in weightlessness is lots of fun. You feel a lightness in your body which you can control easily. You know the distance you have to cross so you gauge how hard to push. We swim in this huge aerial aquarium of a station like space amphibians. At night, when we get up to go to the rest-room, we have to swim across the station without making any noise so we don't wake each other up. We slither around every piece of equipment and any projecting devices....

....When we work at our main post, we only have two little chairs with backs. In order to sit in them without floating up, we have to sit backwards on them; facing the backs of the chairs, wrapping our feet around the base, and holding onto the back of the chair with our hands. We have grown so accustomed to this that our hands and feet seem to find their support all by themselves....Sometimes our body positions become so outrageous that even monkeys couldn't compete with us.

I looked around the station and viewed it with a different

attitude. Now I think of it as home. The whole place looks so familiar. Everything in it is so near and dear to me now. When I look at the interior of the station I feel no alienation, no sense that my surroundings are temporary or strange. Everything is ours. We've touched every square millimeter and object in here. We know exactly where every piece of equipment is mounted, not from documentation, but from memory. Many little details, such as photographs on the panels, children's drawings, flowers and green plants in the garden, turn this high-tech complex into our warm and comfortable, if a little bit unusual, home.

October 5

I woke up and remembered my dream. It was fun that I could dream of something like this. I went home for one day and was supposed to return to space the next day. It was wonderful at home. Lusia is a great cook; Vitalik [their son] and I call her "magic tablecloth." We watched TV and went to bed. In the morning I overslept and almost missed my bus. I arrived to see the rocket on the left, behind the barbed wire fence. It seemed ready to launch any minute. I jumped out of the bus and rushed to the entrance.

There was a group of youngsters who asked me, "Hey man, are you a cosmonaut?"

"No, the cosmonaut is that military man in the bus," I yelled to them so I wouldn't lose time and be late. I ran through the entrance to the rocket.

I heard the noise behind and saw a group of children run after me shouting, "Hey cosmonaut, give us an autograph."

Suddenly there was a tremendous noise, and my rocket flew away. I stood there surprised, thinking, "What will Tolia do alone up there?"

I woke up. Tolia sleeps above me. Everything is all right. I am here....

November 7

The 65th anniversary of the October Revolution. We're celebrating this holiday in space. While we were above the Soviet Union, we watched on TV the Red Square parade. I got a chance to wish my Lusia a happy birthday. My darling wife, she talks so sweetly and tries to cheer us up.

We left the visual [communication] zone, and the station fell silent. Tolia is sitting in the connecting compartment, reading. I'm thinking about running on the treadmill.

We decorated the station with balloons and hung up Lenin's portrait. The station looks festive but we're just not in a holiday mood.

Right after the Red Square parade our families came to the FCC. Lusia looked so beautiful. Tolia's son Sereozha came on- line first. Vitalik asked me to ride on a balloon, so I sat on one and Tolia pulled me along with a string. The kids were happy.

November 8

I woke up early this morning at 6 a.m. Last night I went to sleep at 8 p.m. I wanted to make some observation of the Far East but couldn't videotape it because the video recorder doesn't work.

Absolute silence pervades the station. I fetched some caviar, crab, and quail meat from the refrigerator and heated them up. The Baikal area was covered with snow clear out to the Far East.

The shape of Lake Zey doesn't match the one we have on our maps, I don't know why.

I kept repairing the video recorder. Tolia came to me and said, "I apologize for yesterday." He meant that he had talked for a long time with his family, and I had only a little time left to talk to mine. I didn't answer him, but just handed him the video recorder, and we begin our repair work. We wasted the entire day on it.

November 11

Brezhnev died; Columbia is launched [on the U.S. space shuttle's fifth flight]; and Tolia is sick. I woke up at 5 a.m. and noticed Tolia wasn't in his bed. I poked my head into the working compartment and saw him sitting on the treadmill writhing in pain.

I asked him, "What's wrong?"

"I don't know, I don't feel well, maybe it's something I ate. My left side hurts."

An hour passed, and Tolia was still suffering. I got the Biseptol and activated charcoal from the first-aid kit and gave them to Tolia....When we entered the Soviet visual zone, I told him, "Tolia, I can't keep quiet any longer. I have to report this to the FCC."

He agreed. We were above the Far East, and the communications session wasn't planned, but I went on-line.

"This is *Elbrus* [a twin-peaked Soviet mountain; the crew's code name] calling, please answer."

An operator on duty in Ussuriisk came on-line. I asked him to connect me with the FCC....We explained what happened and left the visual zone.

During the next communication period, at eight in the morning, I talked with Valera [the shift doctor] again. He told me to give Tolia an injection of Atropine.

For the first time in my life I was giving someone a shot.

I took a syringe, removed its cap and said, "Well, Tolia, give me your hip, I'm going to give you a shot."

"Valia, be very careful." I squeezed half of the needle with my fingers so the whole needle wouldn't go in, and gave him a shot. Tolia said that he didn't feel anything. One hour later he felt better.

At the next communication session a group of doctors came on-line and tried to decide whether or not we would

Space flight took a physical toll on the cosmonauts, shown (opposite) on the morning after their return to Earth and (above) with their wives and Lebedev's son three weeks later. In space, Lebedev wrote, "I've become as slender as a cypress, especially in my legs, which look like those of a tadpole."

have to land. It was terrible! Ten years of training, and just one week before setting a new record, we might have to land....

In the afternoon Tolia felt much better. I asked him, "Tolia, what are we going to do? It's our decision whether or not to land. We'll never have another chance to set this record."

Tolia said, "I don't feel that bad right now."

"Well, in that case, let's continue."

I thought to myself, if worse comes to worst, we can always land at a moment's notice. By evening, everybody had calmed down.

Later [cosmonaut Valeriy] Ryumin came on-line, and told us that at 7:16 p.m., the American shuttle Columbia would pass below us about 80 kilometers away. We were in shadow at that time, so although we looked, we couldn't see anything.

November 28

Two hundred days in space. We woke up late, around noon, and began to take inventory in the working compartment. We manufactured an alloy in the *Kristal* furnace. The remaining days we will spend preparing for our return.

By the way, we have a very nice picture hanging on the wall of our station. It was painted by the fellows who built the station. I feel it reflects our life onboard perfectly. It shows a lonesome cowboy tied to a cross, with a gun mounted above, pointing towards him. There is a string tied from the trigger of the gun to an unmentionable spot. In front of the cowboy sways a beautiful naked woman torturing him with a teasing look. In the background stands the cowboy's stallion with sympathetic tears dripping from his eyes, because he understands his master's dilemma. In some ways I think we live the same way on the station, unable to indulge.

December 7

What a hectic day! I didn't sleep well. I couldn't fall asleep for a long time either. Tolia is very restless as well. We crawled into all the corners of the station and looked for damage to the structure, rust or humidity. We vacuumed behind the panels and discovered numerous household items and parts from equipment, which had been sucked behind the panels.

We will land soon and are worried about the reception the FCC will give us; will they be satisfied with our work?

December 9

We are anxious; who knows why. What's it like down there? We're no longer accustomed to life on the ground. Our lives are attuned to this small island in space, and suddenly here we come, back to the Big World! We don't feel comfortable with the idea.

Time to sleep. Tomorrow we will go, toward Earth, toward home....

The next night Lebedev and Berezovoy's Soyuz capsule landed in darkness, tumbling down a snowy hillside in Kazakhstan, 118 miles east of the town of Dzhezkazgan. Freezing and shaken inside their spaceship, they awaited rescue for 40 minutes. The first helicopter to spot them crashed on approach, but its commander survived to warn away any second helicopter attempt during the bad weather. Eventually the beleaguered space travelers were given temporary refuge in a rugged all-terrain vehicle. The next morning, they were returned to the launch complex at Baikonur, but were too weak to walk without assistance.

Now Lebedev continues to work at the spacecraft design bureau and remains a candidate for future flights. He lives in Moscow with his wife and son. □

Hermes

continued from page 37

mission. There is also a lot of time and money tied up in ground stations and ground support."

Lacau faults the current NASA shuttle, born of political and budgetary compromise, as too complicated and sophisticated for many of its missions. "We think that to launch satellites there is no need for man to be present in space. Really, the philosophy of Ariane 5 and Hermes was to have the same vehicle launch all the automatic payloads without man. And then, when required, launch the spaceplane with a few astronauts and a small cargo that can only be handled or used in a manned flight."

He points out that the Soviets' new Energia booster is designed to launch 100 tons to low Earth orbit in automatic mode, as well as to launch the Soviet version of the space shuttle.

"The Soviet approach has the benefit of both the American system and the European idea," says Lacau.

The first components of Ariane 5 will be assembled at the launcher integration site at Les Mureaux, France. The solid rocket boosters will be assembled in French Guiana. The first of the new Ariane 5 assemblies won't roll out until 1991, and the whole vehicle will not come together until about two years later. In 1995, the first unmanned flights are expected to begin from the new ELA-3 launch pad in French Guiana.

As with all previous Ariane launchers, both small and large-scale models will be constructed to check out the system. Much of this work will take place in half a dozen countries in Europe, under the "fair return" principle of the ESA.

"The rule of the game," says Pierre Lacau, "is that each country's industries will receive something from the country's investment in space."

But economics and politics will take second place to the adventure of spaceflight when Hermes begins to fly in a decade or so. As Bernard Deloffre says, "We are lucky enough in Europe to have leaders in a position to make decisions that turn into space programs for us. In humanity you need always to go beyond the limits. You want to *know* what is beyond the limits... There are always people willing to go further and further. You cannot stop that–ever." □

Robert Powers most recent book is Mars: Our Future on the Red Planet, *published by Houghton Mifflin. He wrote on the Los Alamos National Laboratories in the April 1988 issue.*

DATA BASE

1989 Calendar of Galactic Events

JANUARY

Phobos 2 reaches Mars
The Soviet Union's surviving Phobos spacecraft (Phobos 1 is inoperative, due to a spacecraft command error that occurred after launch) reaches Mars orbit at the end of January, and begins maneuvering toward a later rendezvous with the Martian moon Phobos.

FEBRUARY

STS-29 shuttle mission
Discovery and a crew of five astronauts deploy a third NASA Tracking and Data Relay Satellite (TDRS) in orbit during a five-day mission.

MARCH

Commercial Delta launch
McDonnell Douglas becomes the first of the "Big Three" U.S. rocket firms to launch a satellite into space for a paying customer–in this case the government of India.

Phobos encounter
The Soviet Phobos 2 spacecraft makes its close encounter with a Martian moon sometime between February and April. A "hopper" lands on Phobos, while the main spacecraft examines the satellite from only 50 meters above the surface.

APRIL

Magellan mission to Venus
Space shuttle Atlantis and a five-person crew launch the Magellan spacecraft on a radar mapping mission to Venus. Magellan will arrive at Venus in August 1990, and remain in orbit there for eight months, using radar to map the planet's cloud-veiled surface.

MAY

COBE launch
The Cosmic Background Explorer (COBE) is launched aboard a Delta booster into Earth orbit to study radiation left over from the "Big Bang."

AMROC launch
Planned first sub-orbital test flight of American Rocket Corporation's privately developed Industrial Launch Vehicle.

JUNE

SPOT-2 launch
France's second SPOT Earth-observing satellite is launched into orbit on an Ariane rocket (launch date may change depending on status of SPOT-1).

JULY

Pegasus launch
Carried aloft by a B-52 aircraft, the privately developed Pegasus winged booster launches its first payload, a military satellite, into orbit.

STS-28 shuttle mission
Columbia returns to space on a classified Department of Defense mission.

Atlas launch
General Dynamics Co.'s Atlas-Centaur booster makes its first commercial launch, of a U.S. Navy FLTSATCOM satellite.

AUGUST

Voyager 2
The 12-year-old space probe examines Neptune and its moons on Voyager's final planetary fly-by, with the closest encounter targeted for August 24-25.

STS-33 shuttle mission
Discovery rockets into orbit on another classified mission for the Department of Defense.

Titan launch
The first commercial launch of Martin Marietta's Titan rocket carries two satellites into orbit for Japan and Britain.

SEPTEMBER

Ariane launch
Europe's Ariane booster makes its seventh scheduled flight of the year, carrying an Intelsat communications satellite into orbit.

OCTOBER

Galileo heads for Jupiter
Shuttle orbiter Atlantis is slated to send the Galileo spacecraft on its long-delayed mission to orbit Jupiter and probe the giant planet's atmosphere.

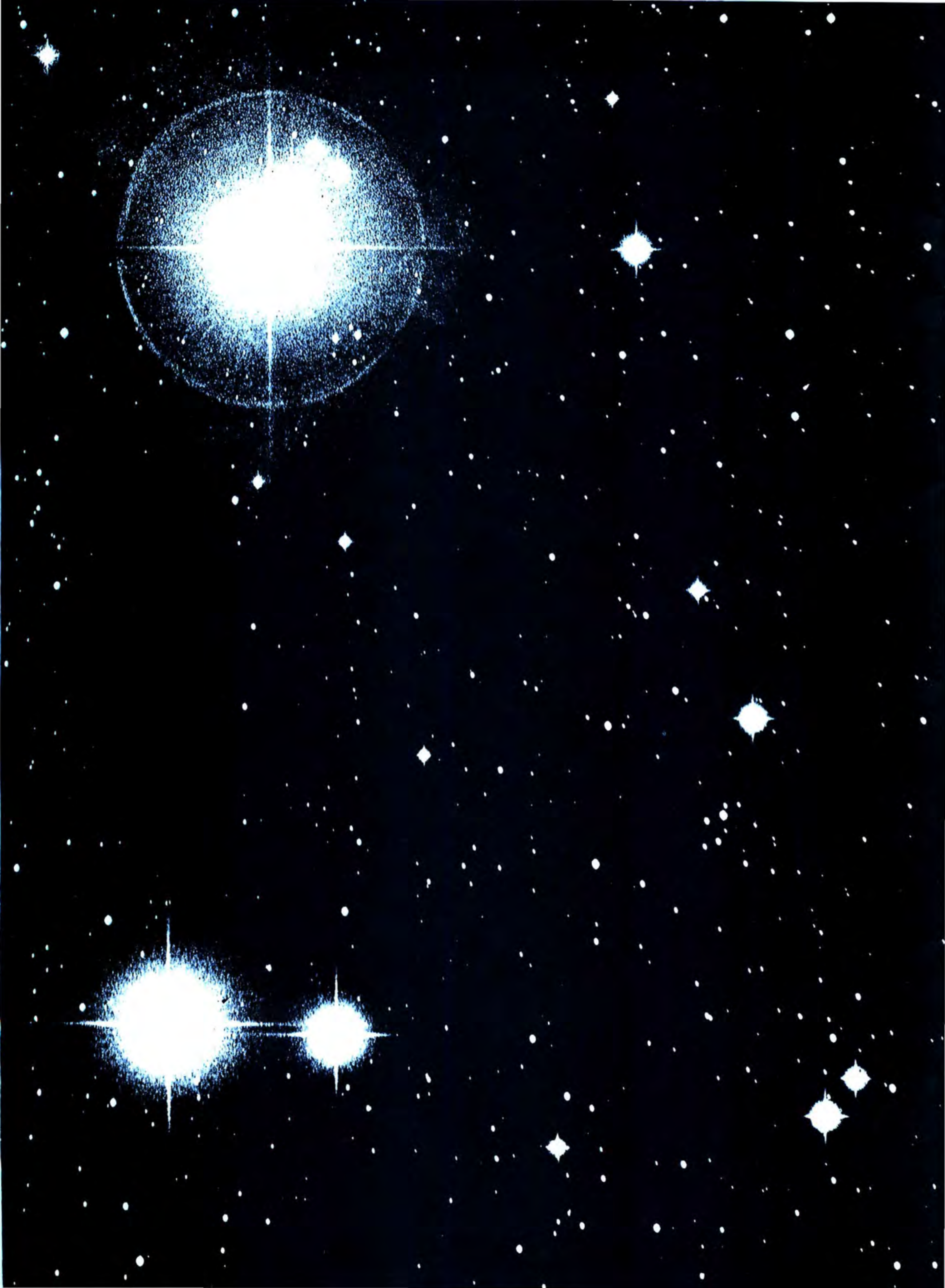
NOVEMBER

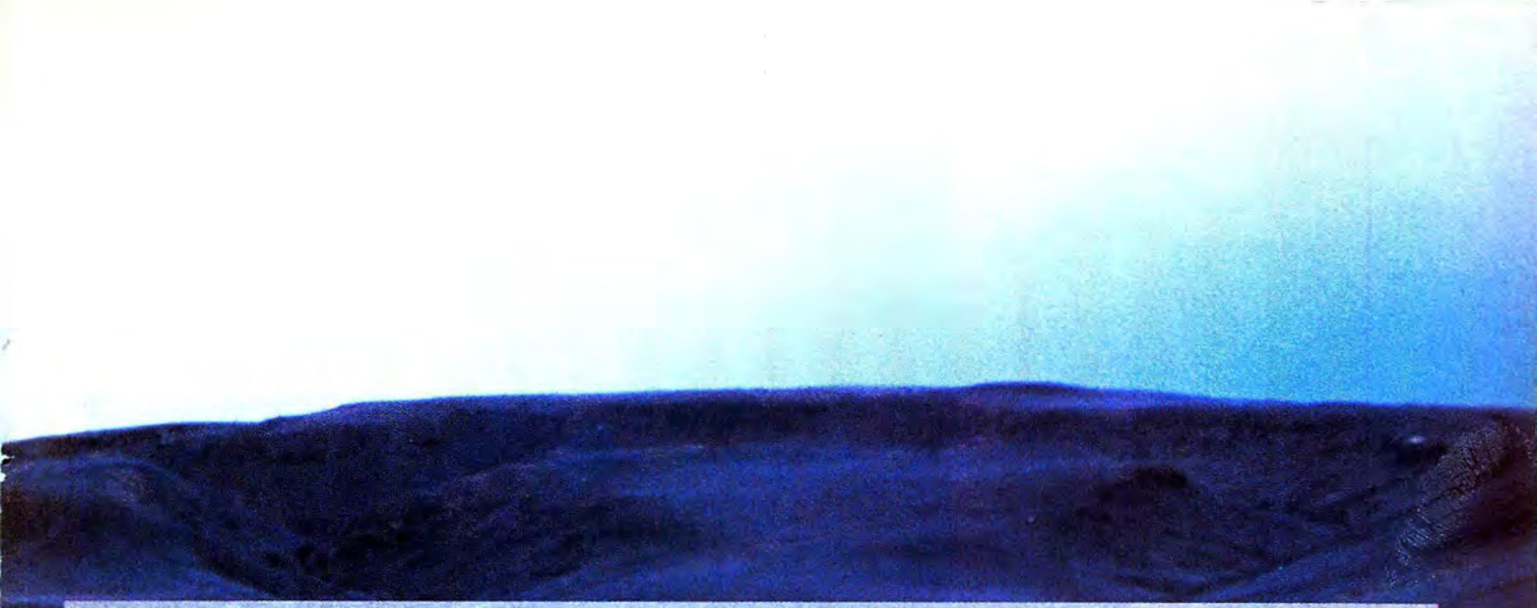
LDEF returns to Earth
Space shuttle Columbia deploys one spacecraft (a SYNCOM communications satellite), then retrieves another–the Long Duration Exposure Facility (LDEF), left in orbit since April 1984.

DECEMBER

Hubble Telescope launched
The long-awaited orbiting space observatory will be released into Earth orbit from the space shuttle to begin observing the Universe with unprecedented clarity.

All launch dates are subject to change.





TO JUPITER AND MARS, VIA

ICELAND

Soviet and American artists met on the rocks last summer to catch a glimpse of other worlds.

By Ron Miller

It was Red Dawn at Landmannalaugar. The Russians were coming, but it seemed as though nothing on Earth could persuade us to leave our hot spring. We'd been on the road for three days, and on foot virtually every waking moment we weren't in the bus. We'd climbed hills, volcanos and hornitos, scrambled across lava flows, forded streams, hiked trails....

The hot spring seemed like a return to the womb, and we weren't going to be so anxious to leave it this time. Most of us had discovered the broad, steaming pool the night before, and had lain in it well past midnight, the sky glowing milkily from an Arctic sun that hovered just below the horizon.

Finally, courtesy and curiosity forced our group of a dozen noisy artists from the hot water into the cold, drizzle-fogged air. Our Icelandic guide Ellin and I strolled out to the main road to see if we could spot any sign of the Russians. We made ourselves comfortable in the bus that had now brought us a third of the way across Iceland in search of other planets.

So far, fun and inspiring as it had been from a tourist's viewpoint, there had been little of specific interest to our specialized group. We were all artists who make a specialty of astronomical painting. Not being able to visit most of the places we depict in our art–it's difficult enough to come up with a couple of thousand dollars to go to Iceland, let alone five or ten billion to go to Mars–we've made a practice of traveling to places on Earth that provide good "analogs" of other landscapes in the Solar System.

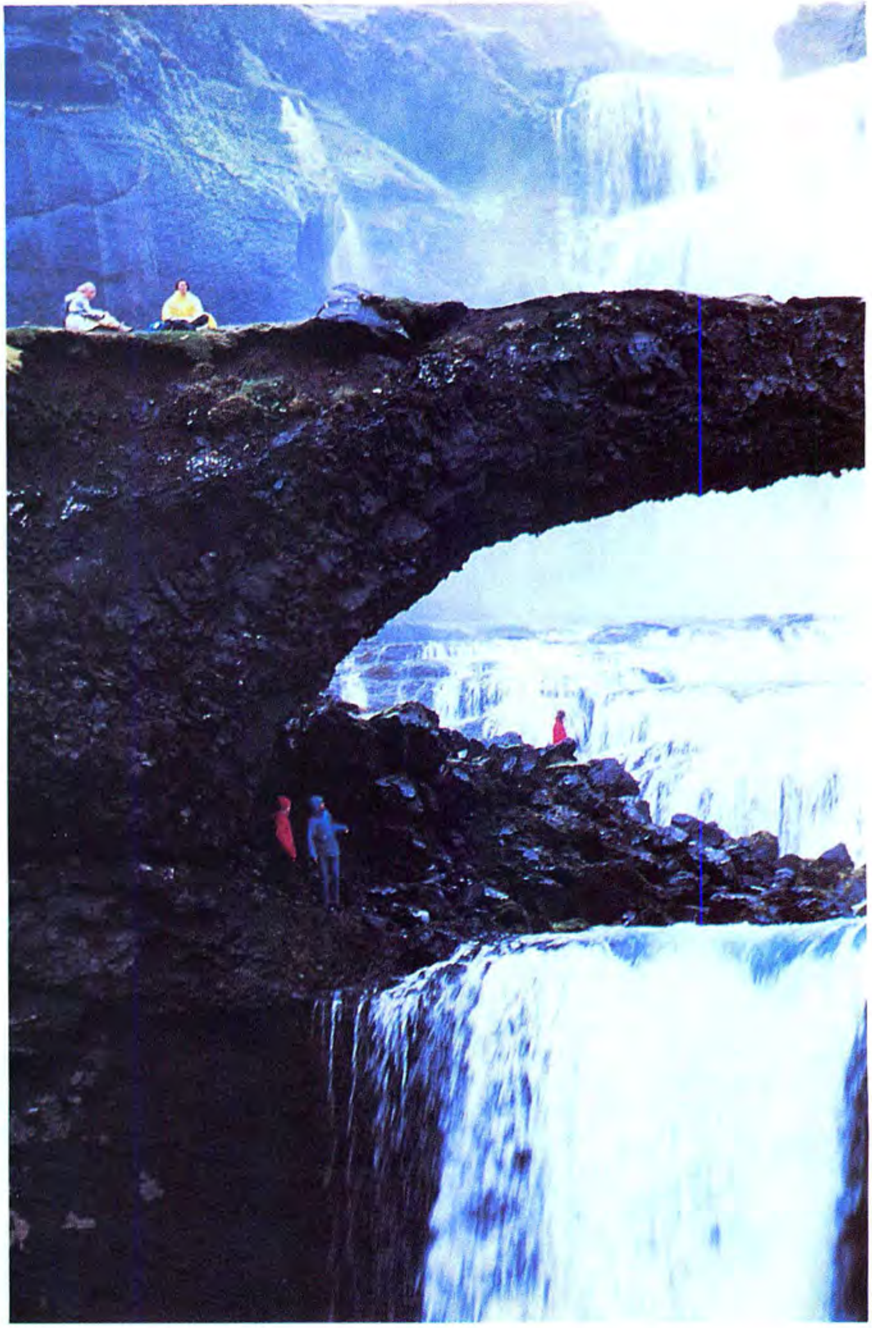
These expeditions, sponsored by the International Association for Astronomical Arts (IAAA), have taken us from the volcanos of Hawaii to the deserts of Death Valley. The workshops not only give us valuable visual stimuli, but serve as a common meeting ground where artists who normally live thousands of miles apart can get together to share ideas.

Since leaving Iceland's capital city of Reykjavik, our company of IAAA artists had been enthusiastic tourists, crying "photo stop!" every few kilometers along the bus route. Our first official halt was Thingvillir, a sheer-walled rift of black basalt where the Mid-Atlantic Rift is exposed, adding fresh volcanic rock to the island. It was the birthplace of the first Icelandic government, and Iceland is still being created here, in a geologic sense.

Not far off was Geysir–the spouting thermal spring that gave its name to all other geysers–then Gullfoss, a breathtaking waterfall that makes Niagara look like a leaky faucet. We finally reached the little town of Fludir, where we'd spent our first night out from the capital.

That night had been clear and bright, with the midnight Sun not far below the horizon. There wasn't quite enough

ALL PHOTOS: MARILYNN FLYNN



The international team of IAAA artists posed for snapshots at glaciers (the author is standing, second from left), explored waterfalls and stopped for frequent sketching breaks.

light for color vision, and the whole scene looked like a daguerreotype, with black-and-white cows placed picturesquely here and there. Rugged, black rocks protruded from the brassy hill behind the hotel like toes from old socks. Ellin told us they were elf rocks, and I headed off with Pam Lee, a California member of our artists' guild, for a midnight stroll among them. Perched atop one of the rocks and silhouetted against the pewter sky, Canadian artist Kara Szathmary was a fey-enough picture to make Ellin's stories seem plausible. I secretly left a krona on one of the rocks just in case.

The following morning's ride took us toward Landmannalaugar and our much-awaited rendezvous with the Russian space artists, who would be joining us for the rest of the trip. On the way we finally came across our first Martian-style landscape—the real reason we were all in Iceland. This vast rolling plain of black volcanic ash, with a squat, snow-covered mountain on the horizon, was as bleak and desolate as we'd ever pictured Mars. We only needed to hold our breaths to imagine ourselves on that alien planet.

From there we descended into a broad, flat valley. There, at the foot of a massive lava flow, was the "hut" where we would spend the next couple of nights: a two-story wooden building with a kitchen and a large bunk room on each floor. For the first time since arriving in Iceland we found ourselves

MICHAEL CARROLL

Left: Mike Carroll based his painting "North Pole of Mars" on the stark, rocky Icelandic terrain. Below: Marilynn Flynn used her photos of steaming explosion craters as the basis for "A Little Hell on Io." Bottom: Anatoliy Veselov's work is typical of the Soviet focus on symbolism and the mythology of space travel.

MARILYNN FLYNN

SPACE ART INTERNATIONAL

thrown together in close quarters, like it or not. Some of us had been friends for a long time, others at least acquaintances, but all too many had been strangers until this summer.

As always, it was good to see Bill Hartmann, astronomer-artist from Tucson, who had brought his wife Gail, daughter Amy and daughter's best friend Shizuka. Bill and I have collaborated on three books, two of which also included the work of Pam Lee (forever more to be known as "Pamella," as she was called by our Russian friends). Though we had worked together on major book projects, this was only the third time Pam and I had met face to face, and here was a chance finally to get to know her better.

My acquaintanceship with most of the others dated from the 1983 IAAA workshop in Death Valley, the only other I had attended. Kim Poor, also from Tucson, was there along with Michael Carroll from San Diego's Fleet Space Theater, Brian Sullivan of the Hayden Planetarium in New York, Joel Hagen, David Hardy (representing the British Empire) and MariLynn Flynn. Fairly new faces (at least to me) belonged to Beth Avery, Mark Hamel, Dennis Davidson, Tom Hunt, Susan Lawson-Bell (from the Air and Space Museum), and Kara Szathmary, who's the incoming president of IAAA.

Despite our common interest in otherworldly subjects, we show a great diversity in style, technique and philosophy. Our work ranges from literally accurate depictions of space hardware to the outright metaphysical, and our styles run the gamut from photorealism to impressionism. It's that variety that makes astronomical art so rich–so much beauty and inspiration, so many ideas.

Some of our group, like Bill Hartmann, had already got busy painting. Others were content to sketch or take photos. I was one of the latter; unlike Bill, who seldom has an opportunity to paint and welcomes the chance, I paint every day at home. I wanted to see as much of the scenery as I could.

Finally, after a couple of false alarms, the new bus arrived–with the Russians!

It was like a family reunion; many of the newcomers were artists we had met while in Moscow at a joint exhibition last October, and they fell on us like bears, hugs and embraces leaving us a little dizzy, shoulders and hands aching from violent Russian handshakes.

We crowded into the small upstairs room where we'd spent the previous night, 25 of us jostling like steerage passengers at Ellis Island. After lunch, we threw our baggage into the bus and were off again, through seemingly endless, desolate Martian scenery, until we arrived at Nyidalur, virtually the dead center of the island, and the isolated hut that would be our home for two nights.

There were twelve Russians in all, including two interpreters, Lena and Natasha. "Slava" Davidov, a graphic designer, was ostensibly the leader of the delegation, but the spiritual head was General Alexei Leonov–cosmonaut, accomplished artist and the first man ever to walk in space. We all took an immediate liking to this barrel-chested legend of the Soviet space program, who was neither aloof nor condescending.

Leonov had learned most of his English in Houston, while training for the joint Apollo/Soyuz mission back in the

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SPACEFARERS

Peace Off Earth

Like it or not, it's OURS.

▼ ▼ ▼

By Maura J. Mackowski

Arthur Woods has a dream. He wants the Star of Peace to shine every night, for every person, in every land. And it looks as though he's put together the ingredients to make his dream come true, including a signed contract to launch his Orbiting Unification Ring Satellite (OURS)–which may become the first work of art in orbit–from a Soviet spacecraft.

Even via long distance from Switzerland, Woods projects the enthusiasm of the true artist and dreamer. In fact, he's both; he makes his living producing art works he describes as "having a lot do with the cosmos." He grew up around Cape Canaveral during NASA's go-go days, but his voice has picked up a Zurich lilt in fifteen years away from the land of the Super Bowl. It also shows a hint of frustration as he describes how his space art project has yet to become a worldwide event for peace, despite his efforts to interest other countries.

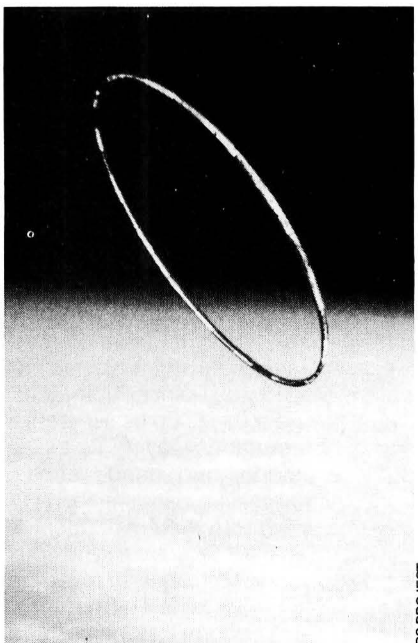
"Six weeks after I sent letters to the Soviets and the Americans, Glavkosmos [Moscow's space marketing agency] signed a [launch] contract," Woods says. "I contacted NASA, and they said they didn't know anything about it." A second request apparently is still orbiting a circular file somewhere in the American space bureaucracy.

Surprisingly, the U.S. media–normally eager to tout efforts to drape whole islands in pink plastic–haven't picked up on Woods' plan to put a ring sculpture in Earth orbit, and it took a bit of circumnavigation for the Soviet press to catch on. Woods says nothing had been written in the U.S.S.R. until a Soviet journalist read in a French newspaper a reprint from a paper in Toledo, Ohio...and then wrote a story in *Izvestia*.

Undaunted, Woods is running his own p.r. campaign, and the $300,000 for a prototype OURS is coming mainly from your average space enthusiast on the street. Fifty Swiss francs (about $35 American) buys a dated, numbered, mounted "piece of the ring"–a snippet of the lightweight plastic material from which the OURS ring will be made, which has been decorated by viewers at Woods' exhibits. An annual donation of the same amount brings a yearly piece of the ring, plus updates.

Woods also offers a student rate, and kids get in free; they need only draw their best artistic expression of OURS to earn a piece of the ring and a place in the collection of kinder-art Woods hopes to publish. Grown-up artists are invited to dance, sculpt, mime, sing or poeticize their feelings in exchange for sponsorship and inclusion in a permanent display.

Woods hopes to beam these messages of peace spaceward from the OURS. The name of every sponsor will be carried aloft, and the project will make a donation of two Swiss francs (roughly $1.40) to UNICEF on behalf of each child and student who contributes.



OURS PROJECT

But is it art? Arthur Woods' Orbiting Unification Ring Satellite

What the Soviets–and, Woods hopes, the Americans–actually launch in 1990-1991 will be a six-meter OURS prototype. He predicts that drag from the atmosphere will cause it to fall from orbit, perhaps after only a few days, but he really would like to see it enshrined for posterity at L-5, one of the stable Lagrange points where Earth's gravitational pull balances the Moon's.

The peace star Woods *ultimately* wants to place in orbit would be a white inflatable ring, a kilometer in diameter, with a cross through its center.

"The circle has had a place in many civilizations," he explains. "We've seen it in Aztec architecture, in Hindu creation legends, among the Mayans and the Tibetans. In the year 2000, we hope to use it to celebrate the new millennium." OURS' big brother would be visible for about ten minutes each month from every point on the globe, and would appear as a circle approximately one-quarter the size of the Moon.

There are, however, a number of small black clouds floating across this sunshiny picture, among them the thought of an orbiting loop of stellar pitchmen silently touting Charlie the Tuna or Morris the Cat. Woods claims that "at $100,000 a hit, there's not much likelihood of that," but he may have been out of the country too long – launch costs like that would be eyewash to the Marlboro Man. Space entrepreneurs, opportunity knocks.

And then there are the astronomers, who bitterly opposed a plan to commemorate the Eiffel Tower's centennial next year with a *six* kilometer ring of spheres, arguing that it would interfere with their view of the night sky.

But Woods isn't letting bureaucracy or thoughts of commercial bastardization get him down. "The more names that are on that sculpture," he says, "the more powerful will be the message. OURS means 'belonging to us.'" □

THE PRIVATE VECTOR

Banking on Tanks

Shuttle fuel tanks are becoming a hot new rental property.

▼ ▼ ▼

By Robert Moulton

"Save ETs!"

The cry went up as soon as President Reagan's new national space policy hit the street early last year.

What caused the excitement was a new provision that the government would make space shuttle external tanks (ETs) available to commercial users for a five year period at no cost, to be used for such things as "research, storage or manufacturing in space."

The external tank is the large, domed cylinder that contains liquid fuel used by the shuttle's main engines during the ascent to space. Normally, just before the shuttle reaches orbit, the near-empty tank is released and allowed to fall back to Earth, burning up in the atmosphere.

But it doesn't have to be that way. The tank is the largest single part of the shuttle launch vehicle, and it contains some 70,000 cubic feet of interior space–usable volume that could be carried all the way to orbit instead of being dropped into the ocean.

Tom Rogers, Chairman of External Tanks Corporation (ETCo), believes that this huge volume, having already been pressurized as a fuel tank, can be repressurized in orbit and used as a laboratory. "We are looking at space real estate here," he says.

ETCo is a commercial arm of the University Consortium of Atmospheric Research, a group of 57 universities and research facilities that is keenly interested in providing room for scientists to work in the microgravity environment of space.

Tom Taylor, head of Global Outpost, Inc., formerly worked with Rogers at ETCo, and is still a minority stockholder in the company. Taylor leaves the idea of repressurizing the tanks in orbit to someone else. He believes an ET should be used first as a "simple, austere near-term platform" for attaching experiments or adding work space for astronauts. Repressurizing the tanks, says Taylor, would be too costly at the beginning.

Another proposal filed with NASA by Wickman Spacecraft & Propulsion Company is anything but austere. The California firm ultimately wants to plant three ETs on the Moon as a testbed for processing lunar materials. The company's founder, John Wickman, optimistically says, "We'd like to see the thing on the surface by 1997."

But according to Jesco von Puttkamer, a long-range planner in NASA's Office of Space Flight, there's a lot more to making ET habitable than meets the eye. "We first would have to design and build a micrometeorite shield and thermal protection shield before anyone can make a living in it. You also need things like Skylab had–stoves, refrigerators, furniture, things that make the tank liveable."

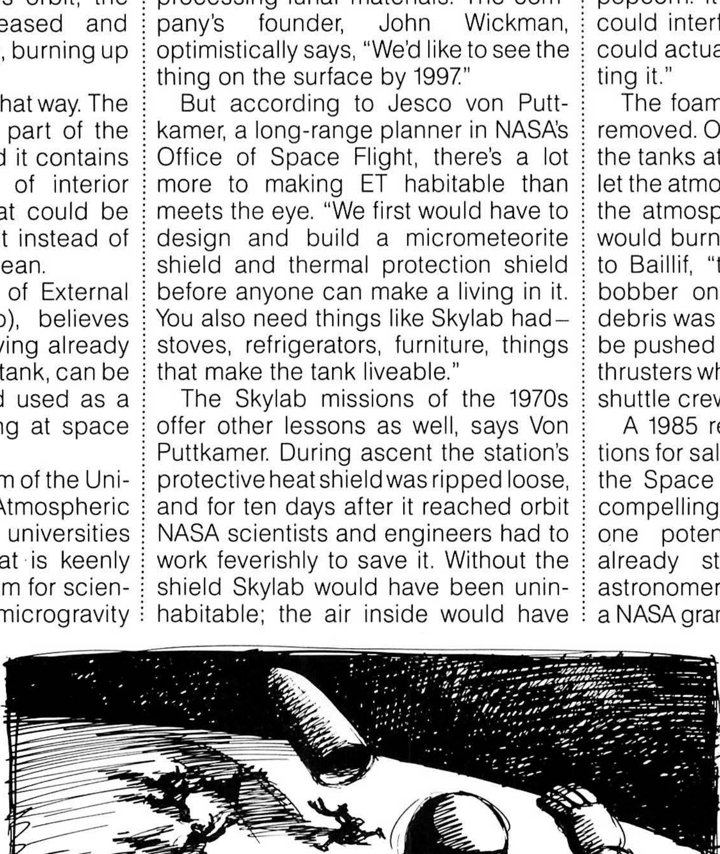
The Skylab missions of the 1970s offer other lessons as well, says Von Puttkamer. During ascent the station's protective heat shield was ripped loose, and for ten days after it reached orbit NASA scientists and engineers had to work feverishly to save it. Without the shield Skylab would have been uninhabitable; the air inside would have been polluted by the "outgassing" of materials due to the extreme heat.

So before the movers show up with stoves, refrigerators and furniture, the ET would have to be drained of its residual fuel by venting it to the vacuum of space. The tank would need to be cleaned out and outfitted with a thermal protection system and a shield to protect it from being punctured by flying debris–some of which would be produced by the tank itself.

According to Faye Baillif of Martin Marietta (the company that builds the tanks), the foam insulation coating the outside of the tanks "could pop off like popcorn. It would float around, and it could interfere with experiments, and could actually damage the tank by hitting it."

The foam may therefore have to be removed. One solution might be to hold the tanks at about a 160-mile orbit and let the atmosphere drag the debris into the atmosphere where it presumably would burn up. Meanwhile, according to Baillif, "the tank would bob like a bobber on a fishing line." After the debris was cleaned off, the tank would be pushed back into a higher orbit by thrusters which would be attached by a shuttle crew.

A 1985 report on possible applications for salvaged tanks, conducted by the Space Studies Institute, is full of compelling reasons to save ET. And one potential near-term user has already stepped forward. Harvard astronomer David Koch, working under a NASA grant, is looking at using the tank as a mount for an orbiting gamma ray telescope.



STAN OLSON

But the fact that commercial enterprises have begun to show interest in the tanks is perhaps the best sign of all. As one space industrialist recently said, "We need commerce in space, and we need to get on the stick and get it moving." And that means having more work space in space. □

REVIEWS

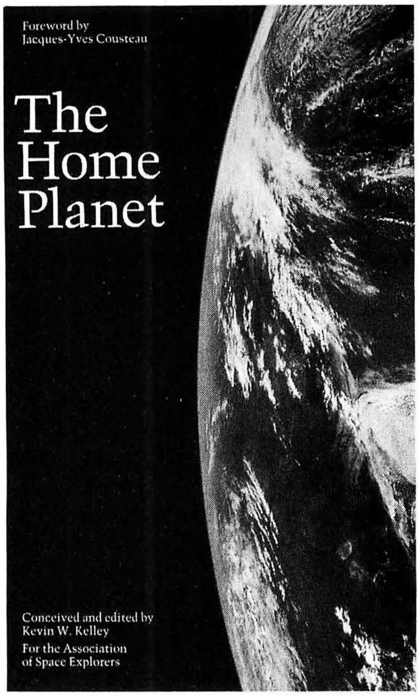
The Home Planet
Edited by Kevin Kelley for the Association of Space Explorers
Addison-Wesley
256 pages. $39.95.

By Patrick Huyghe

Space is just eight minutes away, yet only a handful of us–barely more than two hundred people–have ever been there. The reason, basically, is the expense. Now, for under forty dollars, a book comes along that promises the awe and exhilaration, the anxieties and epiphanies of a trip beyond Earth. What *The Home Planet* delivers is just that: a super-saver ticket into space.

This lavishly produced coffee-table book, which is being co- published by Mir Publishers in the Soviet Union, includes 150 gorgeous color photographs, most of which were taken by the astronauts and cosmonauts themselves during our first quarter century in space. The thoughts, comments and feelings of the space travelers–drawn from a variety of interviews, spacecraft transmissions, articles and books–make up the brief narrative, which adds to, rather than describes, the photographs. Each of these snippets is printed both in the native language of the space traveler and in English. There are 18 countries represented, and 16 languages–testimony to the international arena that space has become.

The short blocks of text relate the experiences of the space travelers, from preflight anxieties to space walks, Moon flights and landings back on Earth. Space, we learn, holds no welcome for its visitors; the astronauts and cosmonauts continually remark on the overwhelming, intense darkness of space. Traveling out into this "blackness beyond conception" has triggered many a nightmare. "The Earth would eventually be so small I could blot it out of the universe," says Apollo 11's Buzz Aldrin, "simply by holding up my thumb."



Earth, of course, is the greatest attraction. Apollo astronaut Tom Stafford noted how emotionally attached he was to "those rough patterns shifting steadily below." All the "good stuff," agrees shuttle experimenter Loren Acton, is down there.

The book's photographs make this easy to appreciate. Our planet becomes a work of art, with each shot of water, land and clouds an abstract masterpiece. To appreciate a masterpiece, one astronaut notes, it's best to back off a bit. For a painting hanging on a museum wall, the recommended distance is about ten feet. For a planet suspended in space, it's about 100 miles.

This opportunity to "look back" has its intellectual as well as aesthetic benefits. "The first day or so," said Sultan Bin Salman al-Saud of Saudi Arabia, "we all pointed to our countries. The third or fourth day we were pointing to our continents. By the fifth day we were aware of only one Earth." This sense of harmony, of one Earth and one people, is repeated often.

"We are all Earth's children," said Alexander Alexandrov, "and we should treat her as our Mother." Other space travelers felt a similar sense of responsibility. "It isn't important in which sea or lake you observe a slick of pollution," remarked Yuri Artyukhin. "You are standing guard over the whole of our Earth."

The Home Planet is a truly wonderful achievement, with only a few minor faults, such as the banishment of all photo descriptions to the back of the book; I got tired of flipping back and forth to learn more about what I was seeing. My only other quibble is with the selection of photographs. Of the 150 chosen, only seven are from Soviet archives. I wish there had been more. And one photograph simply doesn't belong: the book's final shot, a view looking out to the center of our galaxy, which although beautiful, has nothing to do with the central theme of looking back at the Earth.

I loved this trip, and I loved this book. But while there's no denying the tremendous impact that seeing the Earth from space has had on us, what the space program probably needs–for its own sake–is just the opposite perspective. *Don't* look back. Very few of the space travelers quoted here express that attitude, and few of the images capture a pioneering spirit and passion for other worlds.

You catch a glimpse of it in a stirring shot of an astronaut walking across the surface of the Moon, or in a view of the marvelous salt deserts of Iran, with their swirling colors that reminded Robert Crippen more of Jupiter than of the home planet. But only one astronaut appears to have given voice to this extraterrestrial passion. As Michael Collins orbited the Moon alone in 1969, he remembers, "If I looked in the other direction there was God knows what–only me and the rest of the universe. I liked that feeling, being part of the rest of the universe...."

I like that feeling, too. □

Patrick Huyghe is a science writer and television producer based in the New York City area.

Baudry

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people— doctors and trainers, etc., to organize our physical training. That, I think, is a big difference.

But the purely technical things are the same and they work the same way—a lot of simulators and these kinds of systems.

Final Frontier: You have been quite outspoken among the European astronauts, although you're certainly not the only one to say that you cannot make vehicles 100 percent safe and that you are, after all, a test pilot. There is an effort underway to introduce an escape capsule to the design of the Hermes vehicle. Could you comment on that issue?

Baudry: In fact, I am not against the capsule. I think in an ideal world a capsule would be interesting to build, but we are in a *real* world. And the first objective for me will be to have a safe launcher. Ariane 5 [The European launcher for Hermes] was designed for commercial missions, and so far we don't have any proof that Ariane 5 is okay to launch a manned vehicle.

And so I think that in the Hermes program, before spending a lot of time, a lot of money and a lot of energy trying to make an ejectable cabin work, I think that it will be highly desirable to look very carefully at the problem posed by the launcher. If the Europeans have decided to study an ejectable cabin, it's just because they feel that the launcher is not yet 100 percent safe. So that's a basic problem, I think, for Europe.

The ejectable cabin, to me, is a very good design, a very good idea, but it's very expensive. It takes a long time to design it and develop it. It is [additional] weight for the vehicle. It's a complication, and complication goes against safety and reliability.

The last point about the ejectable cabin is that you can not qualify it. You cannot test it [under] real conditions. How do you test a cabin whose flight envelope is from zero to Mach 7 and from zero to 50 kilometers? How do you do that? It would be an impossible test.

I should mention, though, that so far in the Hermes program we are in the definition phase, and it's good to study all possible solutions. You cannot say that Hermes is an operational aircraft. I consider that Hermes is an experimental spacecraft for Europe. It's the first step for Europe in the story of manned spaceflight. You cannot consider the space shuttle as operational, either, but the shuttle can do such a lot of different things—it's really an extraordinary machine.

Hermes is much more modest—not from a technical point of view, but from an operational point of view. Obviously Hermes will use advanced techniques, much more advanced in some ways than techniques used in the space shuttle. But Hermes will have only three men onboard and a cargo payload which will be almost nothing, or very little.

Hermes will bring to Europe a lot of information about this type of spaceflight. We don't have this type of experience. So that's really a big difference, I think. You don't have to compare Hermes with space shuttle or Hermes with the Soyuz or other Soviet vehicles.

Final Frontier: Let's talk a bit about the proposed French space camp at Toulouse, which I understand is very near and dear to your heart. Is it still going to open next year?

Baudry: I think so, yes. It should open next year. It may be at Toulouse; it may be somewhere else. The location is not completely defined.

Final Frontier: Where did your ideas for space camp come from? Were they based on the American space camp in Huntsville, Alabama?

Baudry: In fact, I had the idea in the Soviet Union in 1981 when I saw some Young Cosmonauts. Then in the States, I had seen the space camp [in Huntsville], which is remarkable. They did a great job. I have good contacts with them, and I hope we can have some exchanges when the European space camp opens.

When I came back to Europe [after seeing the U.S. camp], I thought maybe it was time to do something in Europe, in the European way, with European equipment. Because we in Europe don't have a long history in space as the Americans have. But we do have some things. And it's good to explain to our children that space is for everybody, and that [European] people before them have worked in space and have succeeded in some ways.

[Teaching] is different for European kids than for American kids. So I developed a new pedagogical concept, but the object is the same. It puts space in reach for young kids, and explains to them the best ways to carry on in the field they have chosen— astronomer, engineer, controller, doctor or pilot. We explain to them that in the next decade or the next 20 years, "astronaut" is a profession they can make with certainty.

We also will have a simulator, the first Hermes simulator in Europe.

Final Frontier: A different kind of question: on your shuttle flight you followed in the vein of astronaut John Young, who smuggled a sandwich onto a Gemini flight, and you took some wine onboard.

Baudry: I did not drink it, though. It was just a symbolic gift. Astronauts have the right to bring gifts, official or not, and that's what it was—the symbolism of wine going into space.

It's impossible, you know, to drink alcohol on American [space]ships. That's a very strong rule. Some others have the same rule, but they don't apply it. Here in the States, you apply everything.

Final Frontier: That's disappointing, because we were going to ask you what effects alcohol had in zero gravity. Was it a California wine or a French wine?

Baudry: A French wine. You can never be careful enough. □

I know you outrank him Johnson, but he did yell "SHOTGUN" first.

Iceland

continued from page 53

'70s. When he greeted me with a hearty "Howdy, pardner!" in a thick Russian accent, it struck me what Leonov really is. If he were living in my hometown in Virginia he'd be a "good ol' boy."

With the Russians came a lot of vodka. The savvier of us quietly escaped into our sleeping bags, but the others weren't so lucky. Poor Kara came in about 2 a.m., his eyes and most of his body unfocused. "Where is your shirt?" he was asked–a cruelly complex question, I think, for a man with a liquified brain. "The horse ate it," he answered.

"Come on! How did the horse get your shirt in the first place?"

"I lost it playing poker with the palomino."

"How did the horse win?"

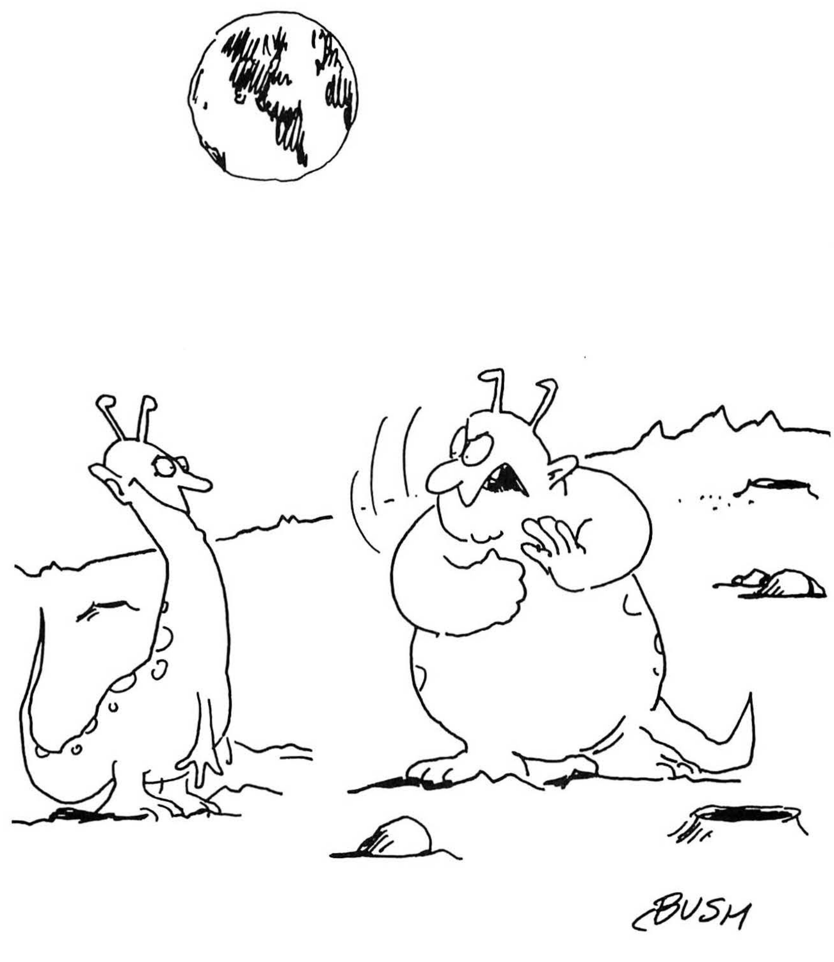
"He lied."

Our first international expedition was to the glacier Tungnafellsjokull–which was promptly dubbed "Tunafishjokull." Our plan was to climb up the edge of the ice, then cross the glacier. To the glee of the Americans, we quickly left the Russians behind. "Bloated capitalists, huh?" we sneered back at the tiny figures below us, who were scattering to find safer things to sketch. Forty-five minutes later, as we watched Ellin pull Dennis out of a crevasse that collapsed beneath his feet, we were reconsidering our assessment of Russian intelligence.

It was an exhausting excursion, but an exhilarating one. We all got some feeling for what the Martian polar caps might be like. We saw clear ice, scores of feet thick, glimmering blue from within. Nearby were large rocks, shattered like loaves of sliced bread by the cold.

That evening back at the hut, the Russians introduced us to the pleasures of vodka mixed with tabasco sauce, and we had a round of self-introductions. Togrul Naramanbekov, an Azarbajian artist, even sang his: a folksong, sadly and sweetly rendered in the twilit cabin.

We left Nyidalur at 8 a.m. sharp in the "Phobus," as we'd christened our vehicle, for the long drive to Lake Myvatn.



One of these days, Norton, POW! To the Earth!

(After *contending* for days with an obnoxious little insect known as the "midge," a kind of oversized gnat, we weren't at all thrilled to learn that *Myvatn* means "Lake of the Midges.")

On the way we stopped at Hverarond, a thermal spring area boasting beautifully-colored mud pots. The air was rich with the smell of sulfur, which reminded Michael Carroll of the Fourth of July. Without stretching our imaginations too far, we could have been standing on Jupiter's sulfurous moon Io. Most of us decided right then to return the next day to paint.

For days we had been hearing reports of the imminent eruption of the volcano called Krafla. Since we were now in the volcano itself, we could see the active area, a black, fuming scab, not half a mile away. Beside me, MariLynn Flynn was chanting intently to herself: "Erupt! Erupt!"

The next morning was devoted to Lake Myvatn's many attractions: Dimmuborgir, the "black city," a maze of fantastic basalt formations; Skutustathagigar, a swarm of explosion craters formed when lava flowed over lakes or ponds–all terrific sightseeing for any painter of alien landscapes.

At Hefty, one of Myvatn's most famous landmarks, we found the closest thing to a forest we'd seen since leaving home. Leonov and I wandered off, distracted by the prospect of mushroom-hunting. The cosmonaut-artist and Soviet hero was, I hoped, also an expert mushroom-hunter. Sauteed Russian-style back in Leonov's room, they were delicious (though, I admit, I let him have the first taste).

That night we showed slides of some of our works, and it was fascinating to compare the Russian approach with our own. We'd had some chance to do this in Moscow the year before, but not at such length. The most obvious difference to me was that the Soviets don't see space exploration with the same technological focus as Westerners do. While we depict our landscapes and hardware with more attention to hard detail, the Russian art seemed "softer" to us, more symbolic and expressionistic.

But there were some Russians who easily would fit into the Western camp–Alexander Petrov, for one, with his realistic, Edward Hopper-like oils. And Kara Szathmary's use of symbolism, if not the symbols themselves, seemed very Russian. It was clear to all of us that this difference in approach could work to our advantage–the Soviets could benefit from our polish and attention to science, and we could learn to include more humanity, romance and history in our own work.

The next night, in a town called Akureyri, we had dinner at a small place near the water. It's a peculiar sensation to walk into a restaurant in a small Icelandic town and hear *Home on the Range* being played on the piano, but by now we were becoming inured to Iceland's surprises.

This would be our last dinner together as a group. Most of us would be on the way back to the United States tomorrow. The Russians would be staying in Reykjavik for a few more days, but only a handful of Americans would remain. After a wonderful dinner of Icelandic lamb, Togrul sang three songs for us. Afterwards, out in the parking lot, Leonov tried his hand at singing, passing the hat. He didn't make a krona.

In a lecture hall in the high school next to the hotel, we had our final show-and-tell sessions, spreading out all the work that we'd done during the last two weeks. Frankly, it was of less interest than the last expressions of friendship we still had time to make.

It seemed a shame that we'd only really gotten close to one another during the last day or two, when we'd stopped segregating ourselves in the bus and in dining rooms and finally begun pairing off and working together. After much trading of artwork and sketches, addresses and notes in English and Russian (to be translated upon returning home) the party reluctantly broke up.

This vast rolling plain of black volcanic ash, with a squat, snow-covered mountain on the horizon, was as bleak and desolate as we'd ever pictured Mars.

▼ ▼ ▼

We'd had a lot of fun, high- and low-jinks, moments of inspiration and passion, the kindling of new friendships and many moments of great peace and beauty. We could all feel the carbon scaling from the carburetors of our souls. We made plans for future international workshops—in Moscow next March and Pasadena and the American southwest next August—as well as an art exhibition that will travel throughout the world. On a smaller scale, a few artists—Michael Carroll and Alexander Petrov, Dennis Davidson and Anatoliy Veselov—made plans to collaborate on paintings.

All of us, whether from the East or the West, had found ourselves in an alien world where even the language had isolated us, and where political and social differences simply didn't matter. We had chosen Iceland for its "Martian" landscapes, and the thousands of photographs, sketches and impressions we brought back will be invaluable to our art.

But there seemed another reason why Iceland was appropriate for our first Western-Soviet workshop. Here, millions of years ago, two vast and opposing forces of nature—fire and ice—met to create a land of incomparable beauty. Now the representatives of two new, great forces have met in this same place.

We can only hope that again great beauty will be the result. □

Ron Miller is an artist and writer in Fredericksburg, Virginia. His most recent book, in collaboration with William Hartmann, is Cycles of Fire.

Liftoff

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"event compression" becomes so intense that even 350 people in two firing rooms can't track each milestone.

Just over a minute before liftoff, a problem! The astronauts adjust the "ports" in their pressure suits, and an oxygen alarm sounds in the crew compartment. Merlino, the iceman, calmly discusses the situation with commander Rick Hauck and his crew, then announces a hold will be called at T minus 31 seconds. But the crew alertly suggests a fix as the clock winds down—they simply purge the oxygen from Discovery's cabin. The numbers return to normal, and the count continues.

At T minus 6.6 seconds, Discovery's main engines roar to life, sending billows of steam from the water-flooded launch platform beneath them. When the clock hits zero, the solid rockets ignite and lift shuttle and crew off the pad on twin columns of flame and smoke. A collective cheer bursts from the firing room: "Yeah! *Go!*" Our words are simple, unpretentious, colored by memories of the pain and horror that had come before.

As Discovery hurtles away from the marshlands, her trail of fire is nearly too bright to watch. No one dares speak above a whisper. "Go baby, go..." The reputation and the very lives of the NASA family are on the line. Someone around me says, "They've passed 73...", a reference to Challenger's final, doomed second. Finally, the solid boosters separate on schedule, to applause and sighs of relief. From the firing room's windows, just at the limit of vision, I see tiny ribbons of smoke trailing from the spent rockets.

The boosters have passed their trial by fire, but the team from Rocketdyne, the company that makes the orbiter's main engines, has several more anxious minutes to go. Their eyes never leave the monitors, even to celebrate booster separation, as rows of telemetry data march across their screens. But when the crew confirms main engine cutoff, they too are free to join in the ovation.

Discovery has returned to space; the long ordeal is over.

Later that day, with astronauts orbiting safely overhead for the first time in too long a time, I reflect that America is back in space to stay, and it seems somehow—*right*. Now it's up to us to make sure the firing rooms are never silent again. □

Dennis Chamberland is a freelance writer and a NASA Safety Specialist at the Kennedy Space Center.

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